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THE UNIVERSITY OF ALBERTA

CHILDREN'S LEARNING IN SCIENCE: A COLLABORATIVE STUDY

BY

BRENDA J. GUSTAFSON

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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CHILDREN'S LEARNING IN SCIENCE: A COLLABORATIVE STUDY

submitted by Brenda J. Gustafson in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

The purpose of the study was to explore how a small group of grade four children made or "constructed" meaning during a science unit on Sound. Another purpose was to describe the experience of using collaborative research methods and to explore how these methods might allow for additional insight into the complexity of learning and teaching science. The methodological framework specifically involved recording classroom science lessons, interviewing study participants, sharing and discussing data with the teacher, and writing a daily journal.

Collaborative methods allowed the teacher to share in the research experience, to gain insight into her students' thinking, to reveal her experience of presenting science, and to examine her presentation of Sound. Collaborative methods, however, required a substantial time commitment, flexibility from the participants, and particular attention to reciprocity.

The children brought their own viewpoints, abilities, creativity, and prior knowledge to the Sound unit. During the Sound unit, each child interpreted the teacher's science in a unique way and gave personal meaning to each aspect of the presentation. These interpretations and meanings were, in part, set against the framework of the Generative Learning Model (Wittrock, 1977, 1981, 1985), and were further interwoven with Schutz's (1971) phenomenological description of a stranger who approaches and tries to understand and adopt a new culture. The view of constructing meaning which arose from this discussion emphasized that the meanings the children constructed were the outcome of a personal dialogue with themselves, and a public conversation with other participants, both of which occurred as the children were immersed in the situational factors of the classroom.

The study offered implications for the Generative Learning Model, alternative framework research, the presentation of science, and pre-service teacher education. The study concluded with recommendations for further research related to how children construct meaning during school science.

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Chapter One

Introduction

Children entering school classrooms already command an impressive capacity to learn and already possess explanations for phenomena in the world which to them, are sensible, relevant, and coherent. Recognition of children's ability to learn about and to explain their world prior to commencing formal education can cause us to wonder about how their learning, and their explanations, might be modified, be changed, or remain uninfluenced by the classroom situation.

An experience connected to these questions about how formal education may influence children's learning and ideas occurred during my master's thesis research. During this research, I spoke with a small group of elementary school girls about their experiences of being involved in the hands-on activity portion of their science program. One of the issues which arose from these conversations was their view of how they learned in science class. The girls drew a clear link between personal participation and access to science materials, and learning and understanding. However, when I questioned the girls individually about their understanding of the content of the science lessons, they were for the most part unable to give 'correct' explanations about which they felt confident and certain even though they received high marks in science. The girls' comments made me wonder about what these girls meant by learning and understanding, and about the nature and content of the explanations which children might possess at the conclusion of a science unit.

Another experience which added to my questions about formal science learning was my observation of the difficulties some of my undergraduate students had during their lab periods. They struggled with ideas and activities usually introduced in elementary classrooms, and I was unsure whether they understood or even believed the explanations which we discussed at the end of the class. Clearly, the process of learning was fraught with difficulties, and I wondered if their past exposures to formal science, and their everyday experiences with science phenomena, had combined to produce personal explanations for the science which my lab periods stood little chance of changing or modifying.

Observations of children and adults in formal classroom situations also drew attention to the classroom presentation of science. In my master's thesis research, the girls identified their teacher as being a dominant influence on their learning, and as the study progressed the restrictions associated with the school structure which this teacher felt emerged through conversations with him. It became obvious that children's explanations of classroom science did not stand in isolation, but in relation to the structure of the school and the society of which it is a part. I wondered if the girls' comments about learning and understanding, and their explanations for science concepts, could further be illuminated by attending to the interactions between the students, the teacher, and factors associated with the school. Certainly a methodology which was sympathetic to the teacher's role in the classroom and yet still included the children would be needed to inform our understanding of these relationships.

Therefore, to begin with, this study is concerned with how and what elementary children learn and understand during school science. What do children mean by "learn" and "understand", or do they even perceive a difference between these terms? What ideas do children already possess about a topic prior to the commencement of a science unit? Do children really change their prior ideas about a topic as a result of science teaching? How much more is involved in learning science than the manipulation of concrete objects? Do children learn through a purely cognitive process of induction or do such ideas as caring about the topic and believing in the explanation play a role? At the conclusion of the science unit, what understandings do the children take away with them? It seems that any one of these questions could lead towards implications for how we approach science in our classrooms.

To focus the study on the children, however, and to a large extent exclude the teacher would deny the reality of the classroom situation. The teacher could well be a key to how the children learn; the teacher also has knowledge and insight about his or her students which could form an essential component of the gathering and analysis of data. A collaboration with the teacher and, to a lesser extent, the students, would represent a relatively new approach to science education research. Consequently, a second focus of this study is the research methodology. Through sharing data with the teacher and involving the teacher in discussions about the study, I will attempt to reveal how both the students and the teacher perceive classroom learning in school science. Some questions which might emerge during the study include: What difficulties does the teacher recognize as being related to teaching and learning science? How does the teacher know the children have learned the science? What implications for the classroom presentation of science might arise from the children's comments and explanations? By considering some of these questions, the interaction between the students, the teacher, and classroom science will be studied in a way which is situational, collaborative, and participatory.

A. Study Questions

The initial questions that will be explored can be asked in a variety of ways, and will take on facets of the following questions as the study progresses:

1. How do children make or "construct" meaning in elementary school science?
2. What is the experience of collaborative research methods, and how do these methods stand to influence the study, the participants, and our understanding of classroom science?

B. Study Purpose

One purpose of this study is to explore how and what a small group of children learn in elementary school science. Another purpose is to share in the experience of collaborating with a teacher, and consider how collaborative methods might allow for additional insights into the complexity of learning and teaching science. My hope is that this understanding will provide us with a somewhat fuller sense of how children and teachers view the classroom experience and live within it.

Literature which is related to these issues of children's learning and collaborative research methods is presented in the following chapter.

Chapter Two

Review of Relevant Literature

A. Literature Related to Children's Learning

I view children as being actively involved in constructing their own learning. In this view, children do not simply respond to information but rather they "actively manipulate or process it" (Peterson, & Swing, 1982, p. 482). This active manipulation of information results in knowledge being "produced by transactions between a person and the environment" (Pope, & Gilbert, 1983a, p. 194). Therefore, children try to understand new phenomena by relating it to ideas and explanations already present within their minds, and this active view of learning suggests that not only is learning and understanding very complex, it is also very personal and unique.

A view of children as being active constructors of their own knowledge is a position frequently presented in recent literature. A variety of educators and psychologists such as Vygotsky, Dewey, Piaget, Ausubel, Kelly, and Donaldson have expressed this view, and a few science educators such as Driver and Pope have further made use of the ideas of philosophers such as Popper, Kuhn, and Feyerabend to support how science has been actively constructed by the human imagination.

This active, personal view of children and learning seems hardly surprising. If anything, we should be wondering how any other view could be seriously considered. Claxton (1986) argues that the human construction of knowledge is "obviously, even trivially true;

[and] that it is only in the context of an educational practice which rests on the stunningly naive 'empty-headed' alternative, that we need reminding of such simple truths" (p. 126). Nevertheless, it is important to discuss this 'empty-headed' or authoritarian view of children and learning because it clarifies the assumptions underlying classroom practice, assumptions that still influence school science. The pervasiveness of this authoritarian view may account for a constructivist view of learning being considered a relatively recent approach to understanding children's learning.

The authoritarian view of children and learning is associated with the beliefs which underlie the realist world view. An examination of these beliefs can begin to illuminate how this view contrasts with the constructivist view.

1. Authoritarian Views of Science and Learning

Pope and Gilbert (1983b) have discussed polar positions concerning ideas of the nature of knowledge; the realist and the constructivist. These two views contain contrasting assumptions about the nature of knowledge, our relationship to the world, and the nature of reality. "In the realist's view, reality is a stable arrangement of subdivisions of objective facts" (p. 249). This suggests that "the world exists in an absolute sense such that absolutely true discoveries [can] be made by suitable trained observers" (Gilbert, & Watts, 1983, p. 62). Reality is something which is out there and it can be objectively observed by any number of people with precision and unanimity. Therefore, knowledge is considered to be "independent of the subjective constructions of the learner" (Pope, & Gilbert, 1983a, p. 194). We simply observe; and our act of observation and what we personally bring to that activity does not influence the outcome. It is this realist view and its implied absolutism which is identified with authoritarian views of knowledge and science.

Authoritarian views of knowledge underlie some approaches to teaching in schools. Pope (1982) claims that authoritarian views of knowledge have dominated Western education and she argues that this has resulted in a cultural transmission approach to teaching.

> Teachers of this persuasion would therefore see the primary task of the educator as the transmission of information, rules, or values which form the 'truths' of one's cultural heritage. In the extreme, the teachers' philosophical approach is that absolute truth can be accumulated bit by bit, subject by subject; their epistemological position is that of the naive realist who views 'true knowledge' as knowledge that corresponds to the world as it is and is, therefore, independent of the subjective constructions of the learner. . . . Traditional teaching methods based upon the cultural transmission approach emphasize the students' role as the passive receiver rather than the active participant. (Pope, 1982, p. 6)

Other approaches to teaching which are based on authoritarian views of knowledge have been called the tabula rasa and teacher dominance approaches (Gilbert, Osborne, & Fensham, 1982). These approaches are similar to what Pope (1982) calls the cultural transmission approach, and the teacher dominance approach is based on the assumption that children bring little knowledge and few beliefs to the classroom. Therefore, the teacher's task is to fill the children with ideas and facts, and the children's prior ideas about the topic "can be directly and easily replaced" (Gilbert, Osborne, & Fensham, 1982, p. 623).

In summary, all of these approaches to teaching emphasize the student's role as a passive receiver of information; and they assume absolute knowledge and the existence of a reality that is independent of our subjective constructions.

This realist view of the nature of knowledge which underlies the authoritarian approach to teaching is also identified with the traditional epistemology found in the positivist, empiricist/inductivist conception of science (Pope, 1982). Positivists strive for a unified view of the world through the application of a method described by Francis Bacon during the seventeenth century, a method which is based on the objective observation of facts and inductive generalizations (De Ruggiero, 1938). In this view, science is value free, empirical, and not influenced by the theoretical frameworks of the observer.

This empiricist/inductivist view can be found in current approaches to teaching science in schools (Cawthron, & Rowell, 1978; West, 1981). Some teachers and educators tend to see school science as the transmission of factual knowledge to students. Cawthron and Rowell (1978) maintain that "a scrutiny of school science texts invariably reveals an implicit epistemological preoccupation with the existence of objective reality and with compatible or equivalent representations of it" (p. 32). In textbooks, "the 'scientist' of school science is revealed as a depersonalized and idealized seeker after truth, painstakingly pushing back the curtains which obscure objective reality, and abstracting order from the flux, an order which is directly revealable to him [or her] through a distinctive 'scientific method'" (Cawthron, & Rowell, 1978, p. 32). Consequently, we should not be surprised that science graduates and the general public who during their education were exposed to this empiricist/inductivist view of science, continue to believe that this view truly represents the nature of science. School textbooks encourage this empiricist/inductivist view and students accept it.

The realist view of knowledge still continues to influence the education system's view of children and science. Teachers may spend classroom time in expository teaching to children who they assume are there to be filled with knowledge. Additionally, science is commonly seen as an objective enterprise where a verifiable, dependable truth is revealed through the use of a method which excludes the observer (Munby, 1976). However, new perspectives in the epistemology of science seem to be in accord with a constructivist view of knowledge which maintains that we are actively and personally involved in the construction of our knowledge. Within this view, science is seen as provisional in nature and the product of the beliefs and frameworks of the individual.

2. New Perspectives in the Epistemology of Science

Current philosophers of science such as Popper (1963), Kuhn (1970), and Feyerabend (1975) argue that observation is theory-laden, and that theory building is an evolutionary process. They also challenge the idea of there being a scientific method (Gilbert, & Watts, 1983).

Popper (1963) suggests that what we should do is to "give up the idea of ultimate sources of knowledge, and admit that all knowledge is human; that it is mixed with our errors, our prejudices, our dreams, and our hopes" (p. 30). Feyerabend (1975) believes theories are not out there waiting to be discovered, but are created by people. Instead of presenting science as a set of absolute facts it should be exposed for the historical, personal phenomenon it really is (Pope, 1982). Driver (1981) notes that Popper and Feyerabend both admit "hypotheses or theories are not related . . . with the so-called 'objective' data but . . . they are constructions, products of the human imagination" (p. 95). The theoretical framework, beliefs, and prior knowledge of the observer influence the act of observation, rendering it a more subjective, human experience.

Kuhn (1970) sees 'normal scientists' as people whose "research is based on shared paradigms [and] are committed to the same rules and standards for scientific practice" (p. 11). Therefore, what the scientist observes is not simply determined by sensory stimuli but by "how the human agent views [the] world" (Cawthron, & Rowell, 1978, p. 45). Donnelly (1979) sees a link between Popper and Kuhn because they both agree that "all facts are theory-laden. All investigations proceed in the light of theory" (p. 498). Clearly, Popper, Kuhn, and Feyerabend believe that observation is not some objective enterprise but instead is related to the beliefs of the person making the observation.

Feyerabend's (1975) belief in a relativistic view of science has led him to argue that we should devise teaching strategies which encourage children to be confident in having a number of viewpoints and to question what is accepted. Children should not be indoctrinated with the view that science is stable, independent of the learner, and absolute. "What we need here is an education that makes people contrary, counter-suggestive without making them incapable of devoting themselves to the elaboration of any single view" (Feyerabend, 1975, p. 164). Students must see learning as a personal exploration which encourages them to theorize and elaborate their own personal constructs (Pope, 1982).

Another aspect of these new science philosophies is the evolutionary nature of scientific theories. Popper (1963) states that "knowledge cannot start from nothing . . . The advance of knowledge consists, mainly, in the modification of earlier knowledge" (p. 28). For Popper, this modification is the result of a process of problem solving and if theories and hypotheses are found to be wanting, they may be replaced by new theories. "At any given time knowledge is provisional and forever open to possible refutation" (Cawthron, & Rowell, 1978, p. 34), and falsifiability is the main characteristic of a scientific hypothesis (Smith, 1982).

Kuhn (1970) views scientific change as paradigms separated by revolutions instead of accumulation of facts through some incremental process. Kuhn (1970) believes that scientific revolutions necessitate the rejection of a longstanding scientific theory in favor of another incompatible with it. This may produce a whole new set of problems and involve the scientific community in the determination of what should be considered an "admissible problem or [a] legitimate problem-solution" (p. 6). If this is the case, "socio-psychological factors are no longer at the periphery of the scientific process, but are at its very core" (Cawthron, & Rowell, 1978, p. 40).

Popper, Kuhn, and Feyerabend contend that scientific knowledge is relativistic in nature, influenced by the theoretical framework of the observer, and subject to continual change and revision. These beliefs resemble the assumptions found in the constructivist view of learning and are in contrast to the realist view linked with traditional ideas about science and learning. Associated with the constructivist view of learning is George Kelly (1955) who "pointed out that all theories are [derived from] hypotheses created by people and that, although they may fit the known facts at any particular time, they may eventually be found wanting and eventually be replaced by a 'better theory'" (Pope, 1982, p. 6). This statement echoes the ideas of Popper, Kuhn, and Feyerabend. In the next section, I will explore the constructivist view of learning more fully.

3. Constructivist View of Learning

George Kelly (1955), a cognitive psychologist, developed a theory of personality for which he coined the term 'constructive alternativism'. Although Kelly's main concern was therapeutic practice and the generation of a theory of personality, some of his basic assumptions about human behavior seem "potentially applicable to many teaching and learning issues" (Pope, 1982, p. 4). Vygotsky, Piaget, Bruner, Ausubel, and Donaldson also have cognitive theories which seem, in part, to be in philosophical agreement with Kelly's assumptions.

Kelly's main idea is that each person constructs a unique interpretation of the world; consequently, "persons differ from each other in their construction of events" (Kelly, 1955, p. 55). This construction is a process in which we actively reach out to understand the world, and Kelly (1955) maintains a person "creates [his or her] own way of seeing the world in which [he or she] lives; the world does not create [his or her] view for [him or her]" (p. 12). This active construction of events enables people to erect a representational model of the world which is then used to guide behavior. However, these models are neither rigid nor absolute but over time are subject to "revision or replacement" (Kelly, 1955, p. 15). Perhaps this suggests that we should consider whether our constructions of knowledge should be more accurately called *reconstructions* of knowledge (Berry, 1982).

Kelly's ideas are consistent with the views proposed by Popper, Kuhn, and Feyerabend. It seems they all recognize the uniqueness of the individual; the relativistic, human nature of knowledge; the active stance we have towards the world; and the tentativeness of our interpretations. Other educators and psychologists have recognized the value of viewing knowledge and people in this way and have attempted to apply these ideas to children and how they learn.

Vygotsky (1978) believes people actively participate in their own existence. Thus, Vygotsky describes development and human activity as a dialectical process involving an intertwining of external (cultural) and internal (biological) factors. He calls this relationship between the biological basis of behavior and the social conditions in and through which actions take place a "functional learning system." Functional learning systems are unique to the individual and these systems are subject to evolutionary and revolutionary change. This may imply that children are influenced by their unique prior experiences, may have a number of interpretations for a single event, and may demonstrate various degrees of willingness to modify their beliefs.

Piaget and Bruner also view children as active agents in constructing their own reality and contend that children understand the world to the extent that they are willing to act upon and make sense of the world (Bruner, 1960; Cawthron, & Rowell, 1978; Driver, 1981; Driver, & Easley, 1978; Duckworth, 1964; Osborne, & Wittrock, 1985; Pope, & Gilbert, 1983b). Donaldson (1978) states that our relation to the world "is active on our part from the beginning. We do not just sit and wait for the world to impinge on us. We try actively to interpret it, to make sense of it, we represent it to ourselves" (p. 67). Popper (1963) also asserts that "without waiting, passively, for repetitions to impress or impose regularities upon us, we actively try to impose regularities upon the world. We try to discover similarities in it, and to interpret it in terms of laws invented by us" (p. 46). Clearly, this active stance implies that learning is not a passive enterprise but rather one in which children actively try to make sense of what they perceive.

Several researchers have also explored the role prior knowledge plays in our construction of the world. Ausubel's learning theory plays a prominent role in this area by attempting to explain "the part played by prior knowledge in organizing new learning and building it into the cognitive structure of the learner" (West, & Fensham, 1974, p. 79). Ausubel believes that the learning situation itself combined with our own existing personal knowledge can influence our learning. Piaget also agrees that children already possess many ideas about things and this stands to influenced how they make sense of their school experiences (Cawthron, & Rowell, 1978; Driver, 1981; Osborne, & Wittrock, 1985; Piaget, 1972). Donaldson (1978) comments that children's interpretation of an event is influenced by their "knowledge of the language, [their] assessment of what we intend (as indicated by our nonlinguistic behavior), and the manner in which [they] would represent the physical situation to [themselves] if we were not there at all" (p. 68). This suggests that learning outcomes depend on the environment, the learner, and the learner's prior knowledge. When combined with the learner's active stance, the result is a relativistic, human view of knowledge that is subject to revision and reconstruction.

In summary, some educators, some psychologists, and some science philosophers view our stance in the world as being one of active participation. This quest to understand, and the role of prior knowledge in understanding, results in ideas which are unique and subject to continual change and replacement. In science education research, this constructivist view of learning can inform us about how children understand school science. It can also help explain observations about the difficulties children experience in science and perhaps account for the persistence of children's personal ideas about science content. This area of science education research has been referred to by a variety of labels: alternative framework research (Driver, 1981), alternative conceptions (Gilbert, & Watts, 1983; Minstrell, 1983), children's science (Gilbert, & Watts, 1983; Osborne, Bell, & Gilbert, 1983), misconceptions (Eaton, Anderson, & Smith, 1984; Gilbert, & Watts, 1983), and preconceptions (Anderson, & Smith, 1984).

4. Alternative Frameworks in Science Education

Some generalizations which have arisen from alternative frameworks studies include the following (Adapted from Osborne, &

Wittrock, 1983):

1. young children entering elementary classrooms hold alternative beliefs about science phenomena which may be quite different from those held by scientists,

2. if children's ideas are changed by the teacher's presentation of the lesson, the changes are sometimes quite different from those intended,

3. children do not really change their ideas of how and why things behave as they do as a consequence of science teaching, and

4. older students and adults may still hold fast to many of their original ideas about science they had as younger children.

Researchers suggest a number of factors which may influence children to develop and retain alternative ideas about science content. Driver (1981) believes that children actively use observation and induction to try to explain the world. She adds that there "is also a creative and imaginative element involved on the part of each child in constructing the meanings [the child] imposes on events" (Driver, 1981, p. 95). Children's constructions of alternative ideas about science can also be influenced by continual exposure to society (Solomon, 1983):

> In daily conversations and through the mass media, our children are confronted with implicit assumptions about how things move, their energy and their other properties, which can be directly at odds with the scientific explanation that they learn in school. Outside the school laboratory, these adolescents are continually being socialized into a whole repertoire of non-scientific explanations. Examinations of newspaper reports and everyday language makes clear the pervasiveness of this subversive process. (Solomon, 1983, p. 49).

Young children arriving in classrooms already have many ideas about science which they have constructed through personal experience and exposure in society. These ideas such as spiders are not animals or plants only grow in gardens appear coherent to the children, and researchers have discovered that these beliefs are both stable and persistent (Driver, Guesne, & Tiberghien, 1985).

The language of school science, its content, and its teaching methods provide a further challenge for children. In school science, children are confronted both with new terminology and familiar words such as particle and work, now bearing unaccustomed definitions (Driver, 1981; Gilbert, Osborne, & Fensham, 1982; Munby, 1976; Osborne, & Freyberg, 1985; Sutton, 1980). If children are not aware that some words take on new meanings in school science, then they continue to interpret the words within "the context of ordinary language, rather than within that of scientific language" (Munby, 1976, p. 117). Thus, because of the terminology used, the teacher's interpretation of the purpose of the science lesson and the child's understanding of that purpose might be quite disparate. In school science, then, we may be asking children not only to learn content, but also to cope with vocabulary which conflicts with their prior knowledge.

Solomon (1983) believes that in school science we expect children to "be able to think and operate in two different domains of knowledge and be capable of distinguishing between them" (p. 50). Solomon (1983) identifies two coexisting spheres of everyday notions and scientific explanations and further relates them to Schutz and Luckmann's (1973) discussion of life-world knowledge and symbolic universes of knowledge. Briefly, in our normal or 'neutral attitude' we tend to loosely categorize our experiences. "These are then reinforced by communication with others and by language itself, which gives this 'life-world' knowledge both social value and great persistence" (Solomon, 1983, p. 50). This life-world knowledge contains the alternative ideas about science which children bring to our classrooms. In school science, children learn other knowledge systems which "stand above [their] life-world structures, seeking to explain [their] experiences in another province of meaning, and forming what have been called 'symbolic universes' of knowledge" (Solomon, 1983, p. 50). Children are then faced with the task of trying to cope and understand within the context of two different domains, and school science becomes a problem of translation.

Schutz and Luckmann's (1973) theory is related to Donaldson's (1978) notion of embedded and disembedded thought. Like life-world knowledge, embedded thought deals with things and reasoning in the context of familiar patterns and events. Disembedded thought is that which "no longer operates within the supportive context of meaningful events" (p. 75). Donaldson argues that for school to be more meaningful to children it must present human sense situations with which children are familiar. However, Solomon (1983) expresses doubt about this contention and instead argues that "the deepest levels of understanding are achieved . . . by the fluency and discrimination with which we learn to move between these two [life-world structures and symbolic domain] contrasting domains of knowledge" (p. 58). Certainly children are faced with numerous challenges in school science which could result in some children retreating from the subject, others partially accepting the ideas, and still others becoming fluent in alternating between two domains of knowledge.

One reaction to the recognition of children's alternative ideas about science has been to devise strategies for changing these ideas

(Anderson, & Smith, 1984; Driver, & Erickson, 1983; Hewson, 1981; Hewson, & A'Beckett Hewson, 1984; Johnson, & Howe, 1978; Olson, 1982a; Osborne, Bell, & Gilbert, 1983; Osborne, & Wittrock, 1985; Pines, 1980; Posner, & Gertzog, 1982; Posner, Strike, Hewson, & Gertzog, 1982; Rowell, & Dawson, 1985). Prominent among these is the work done by Hewson (1981) who maintains that four conditions must be satisfied for change to take place: "there must be some dissatisfaction with the initial conception; the new conception must be intelligible; the new conception must be initially plausible; and the new conception must be fruitful" (p. 387). To create initial dissatisfaction, researchers try instructional conflict, discrepant events, specific teaching sequences, or modified instructional strategies designed to challenge children's alternative ideas. However, this strategy assumes that children will readily see these anomalies and that learning is promoted by the resultant conflict. Claxton (1986) warns that "an equally likely response to being challenged or 'confronted' is a defensive entrenchment, and a denial or evasion of the learning opportunity" (p. 127). He further contends that "children generally learn from discovering alternative ways of achieving a successful performance rather than from attempts to rectify error, failure, or conflict" (Claxton, 1986, p. 127). Gunstone, Champagne, and Klopfer (1981) also caution that humans have a large capacity for storing conflicting principles. Therefore, a discrepant or conflicting event might not replace an idea but rather be stored alongside the view it was intended to supersede.

5. Generative Learning Model

From the recognition of children's alternative frameworks, factors influencing framework construction, difficulties with the language and content of school science, and ideas for changing alternative frameworks have come suggestions about how these observations can be incorporated into some model of learning.

Driver and Erickson (1983) have observed that alternative framework researchers seem to share certain assumptions about knowledge and learning, and share a commitment to some form of constructivist psychology. This shared view of knowledge and learning underlies the Generative Learning Model which was originally presented by Wittrock (1974, 1977, 1978, 1981, 1985), and has since been applied to alternative framework research in science by Osborne and Wittrock (1983, 1985).

Wittrock (1978) begins with the assertion that learning involves relating sensory information to existing knowledge, and he claims that he did not originate this idea, but rather this is a view which can be traced to ancient Greek and Rome. Wittrock (1977, 1978, 1981, 1985) finds this active view of knowledge construction to be compatible with current brain research and offers that:

> In the context of [history] . . . and the recent research on the human brain, imagery, and semantic and verbal processing, I suggest that learning in schools be reconceived as a generative cognitive process . . . From this point of view, it is plausible that learning is basically a process of relating stimuli to previous experience, from which one induces and elaborates meanings and representations. According to this model, learning with understanding is the process of transferring previous experience to new events and problems. (Wittrock, 1977, p. 176)

In Wittrock's view, if learning involves relating new information to existing ideas, the construction of meanings, and the eventual transferring of these meanings to new situations, then what must be important to learning is the child's existing ideas and his or her ability to generate links between these ideas and incoming stimuli. Osborne and Wittrock (1985) summarize the key postulates of the Generative Learning Model:

1. The learner's existing ideas influence what use is made of the senses and in this way the brain can be said to actively select sensory input.
2. The learner's existing ideas will influence what sensory input is attended to and what is ignored.
3. The input selected by the learner, of itself, has no inherent meaning. Just the sensory stimulation is received by the student who must then construct meaning for this stimulation.
4. The learner generates links between the input selected and attended to, and parts of memory store.
5. The learner uses the links generated and the sensory input to actively construct meaning.
6. The learner may test the constructed meaning against other aspects of memory store and against meanings constructed as a result of other sensory input.
7. The learner may subsume constructions into memory store.
8. The need to generate links and to actively construct, test out, and subsume meanings requires individuals to accept a major responsibility for their own learning. (Adapted from Osborne, & Wittrock, 1985, p. 64, 65, & 66)

This learning model can account for observations which have emerged from alternative framework research such as the observation that children's pre-existing ideas can influence science learning, that children sometimes cling to pre-existing ideas despite science teaching, that children can display a variety of ideas after a science lesson, and that learning is something that only the learner can do. These observations, and the ability of the Generative Learning Model to provide an interpretive framework for them, has led to some implications for teaching and learning which have focussed on the importance of encouraging children to accept responsibility for their own learning, and on the importance of the teacher's role in influencing what the children select and give attention to, what the children generate links to, and what meanings the children construct. Perhaps there are additional considerations, however, about the potential classroom implications of alternative framework research which should also be considered.

6. Issues Regarding Implications for the Classroom

Despite acceptance of the existence and legitimacy of children's alternative frameworks, however, researchers have tended to view these frameworks as problematic. The overwhelming reaction has been to suggest ways in which children could be encouraged to abandon these alternative ideas and embrace 'correct' scientific explanations. Perhaps what should be asked here is, should children's views be altered?

The theoretical background of alternative framework research maintains that knowledge is subjective and tentative in nature, and constructed as people actively try to make sense of the world. It seems, however, that such a view of knowledge is set aside in asking the question, What should we do about children's alternative frameworks? This question suggests a view of knowledge that seems contrary to the view of knowledge which underlies alternative framework research. Instead of recognizing that alternative frameworks are an inevitable outcome of children's subjective constructions and that these frameworks possibly represent ideas which children consider during the evolution of some personal understanding, we become concerned that children do not have the 'correct' interpretations of the science. The idea that there is one correct, unassailable answer and the implication that there exists an authoritative view, is reminiscent of the realist rather than the constructivist view of knowledge.

There is also the ethical question in asking children to change their ideas. Olson (1982b) offers:

> Candy puts the problem clearly in focus: 'Yet it is in the area of deliberately contrived personal paradigm shift that the adult educator must be particularly cautious. For a start, such major interventions in people's construct systems raise the very real problem of how a person immersed in one particular set of personal constructs can construe and, ultimately, come to use another (hopefully more functional) 'mind set' or personal paradigm. Moreover, there is the profound ethical question of what right any person has to imply that another should modify (or more critically, completely reconstruct) his or her world view'. (p. 74)

Perhaps the asking of this question about how we can guide children to adopt 'correct' scientific explanations is inevitable when we begin to talk about science in school. Curricula, textbooks, and evaluation all stress content for which the student is held accountable, and society increasingly demands 'competent' school graduates. White (1979) has pointed out that society influences what is valued in schools; he identifies several movements which are currently influencing society's demands for competence. He concludes that "along with members of other fields, science educators must accommodate to this demand and will have to deliver competence" (p. 2). White (1979) then illustrates his view of competence by discussing achievement, mastery, and proficiency.

Perhaps if children are to succeed in the school system, they must 'learn' the 'correct explanation' or 'process' regardless of the existence of opposing alternative frameworks. Even if we recognize the validity of the underlying assumptions of the constructivist view of learning, resistance from the society in which we live, and the school structure which is influenced by that society may instead result in the promotion of a realist view of the nature of knowledge. Maybe this in part explains why the constructivist view of learning is still viewed as being relatively novel despite its obvious common sense.

Some difficult questions remain to be asked: What do children really learn in school? What is the nature of children's learning in school? How do teachers view children's learning? and What factors associated with the structure of the school might influence children's learning and understanding in science? These questions may in part be explored by entering a classroom and spending time observing and conversing with the students and the teacher. Perhaps by collaborating with classroom participants we can begin to understand how children learn in school science and the factors which stand to influence the learning process.

B. Literature Related to Collaborative Research

1. General Background

Collaborative research, action research, and collaborative action research are just some of the labels given to methodologies which emphasize a situational, collaborative, participatory, and self-evaluative approach to classroom-based research. Although some authors differentiate slightly among these terms, others seem to treat them as synonyms and claim they share the common characteristic of collaboration among study participants to: (a) identify a problem; (b) negotiate a method; (c) gather, analyze, and interpret data; (d) present the findings; and (e) decide upon subsequent action (McCutcheon, 1981; Nixon, 1981). This study began as a cooperative study because the initial study questions were not formed in collaboration with the cooperating teacher. Instead, I independently generated the study questions and then searched for a teacher who shared my concerns about children's learning in elementary science, and perhaps would be willing to move from this cooperative stance to a more collaborative, sharing position.

Action research was originally introduced by Lewin (1944) and has since been identified as having the potential to address a variety of concerns: (a) a recognition that problems chosen by researchers are often too removed from practice, (b) the observation that educational research is done by those outside the classroom for the benefit of people outside the classroom. (c) a concern that teachers lacking a background in statistics may have difficulty interpreting traditional empirical research, and (d) a desire to close the gap between research and practice (Carson, & Couture, 1988; Ingram, 1959; Nixon, 1981). Evans (1982) concludes that interest in collaborative research "has been stimulated by the widely acknowledged need to conduct research and develop models that will lead to a greater use of research knowledge in school and instructional improvement efforts" (p. 144).

A desire to make research more relevant to classrooms and teachers is often stated as the rationale for other qualitative research methods such as case studies and ethnographies. Action research, however, goes beyond the participant and non-participant observational method of a case study, and the claims of ethnography to provide a potential synthesis of the production of knowledge and the demonstration of its applicability to educational practice (Cohen, & Manion, 1980; Woods, 1986). Action research further claims that ongoing collaboration with the teacher and the children allows the participants to deal with problems which are of immediate concern and it may increase the benefits participants may derive from the research.

Some of these benefits may include: (a) an increase in understanding the classroom, (b) an increase in the potential for making informed decisions, (c) an enhancement of the teacher's feelings of professionalism, (d) a stimulation of discussion about the teacher's classroom, (e) a general sharpening of perception, and (f) an opportunity for children to reflect upon what they do in the classroom.

Action research encompasses an eclectic range of research designs. Teachers may work alone, or with a group of teachers, or in conjunction with university based researchers. The scope of the issue under study may be narrow or broad and the timeline may range from a few days to several years. Methods may include the writing of diaries, observation of classrooms, interviewing, recording classroom lessons, teaching some lessons, and collecting samples of tests, notes, and assignments. This eclecticism can in part be attributed to the ongoing collaboration which can lead to the modification of the initial research problem and the gradual evolution of the methodology. Therefore, collaboration involves a recognition of the valuable insights and knowledge that each person brings to the study, and an ability to work in an atmosphere of "constant change" (Trubowitz, 1986, p. 21).

Action research is not without its problems. De Bevoise (1986) warns that "idealogues with rigid agendas for reform and practitioners who distrust theory and resist change will probably encounter frustration in initiating or responding to a collaborative project" (p. 11). Therefore, the ability to develop an atmosphere of mutual respect, cope with change, be flexible, and maintain an ongoing communication are essential elements of successful collaborative research (Cohen, & Manion, 1980; De Bevoise, 1986; Ingram, 1959; McCutcheon, 1981; Root, 1981). Cohen and Manion (1980) suggest that if research is to progress and be beneficial then it is necessary for the teacher to be favorably disposed toward the project, to be truly involved, and to know the objectives and what these imply. McCutcheon (1981) advises that the teacher and researcher should have equal but not identical roles and responsibilities. Clearly, the selection of the teacher and the working relationship which is established is an important part of any collaborative research effort.

A wide variety of issues can be explored using collaborative methods. Many teachers have identified and studied topics of immediate classroom concern such as discipline, evaluation, diagnosing learning difficulties, group behavior, curriculum topics, and program implementation (Carson, & Couture, 1988; Ingram, 1959; Nixon, 1981). Nixon (1981) adds that action research can also inform "the teacher's judgement about such things as how children learn, what the critical moments in this learning process are, and how and when the teacher should intervene so as to facilitate this process" (p. 6). These interests about how children learn and the diverse ideas they may have at the conclusion of a lesson are issues found in alternative framework research.

2. Alternative Framework Research Which Resembles Collaborative Research

The majority of alternative framework research has relied on 'staged situations' outside of the classroom where either the child or the teacher was studied in isolation. Techniques that have been used to formulate taxonomies of children's ideas about science topics include word association, free association, concept propositional mapping, interview about instances, interview about phenomena, written tasks, rule assessment, observational methods, and some naturalistic studies (Driver, & Erickson, 1983; Sutton, 1980). These techniques were useful because they initially provided a way to explore the ideas children have about science. In recent years, there has been a recognition that studying children as they participate in their science classroom may provide additional insight into the concrete, complex situation with which the teacher must deal. Several researchers have studied the child in the classroom while maintaining an ongoing collaboration with the teacher (Baird, 1986; Osborne, 1985; Tasker, & Osborne, 1983).

Baird (1986), an Australian researcher, is involved in a science learning study called the Project for Enhancing Effective Learning (PEEL). The premise for his methodology is that school learning is inextricable linked with the teacher and therefore, to explore the issue of learning and how it occurs, both the teacher and students must together be involved in the research. Although Baird (1986) and his colleagues devised the notion of PEEL in 1984 and admit it represents an extension of their earlier research on learning, they still call it action research and state that:

> In action research, the participants act as researchers - - they observe and collect information on an instance of learning, reflect on and evaluate these observations, then use these evaluations to clarify issues or act to change procedures. These new procedures are then subjected to the same research process. Students, teacher, and myself were engaged in researching changes in classroom procedures, attitudes, and behaviours as students trialled new procedures. (p. 14)

This methodology continues to be used by Baird (1986) although he admits that after his 1985 research he observed that these methods

> neither provided all the answers, nor even produced a cohesive package of techniques which can be directly applied elsewhere . . . . however, [it has] revealed some of the inherent complexity of the undertaking, indicated some directions in which to go, and provided some useful lessons for what not to do. It has demonstrated that, for success, the teacher must match high levels of commitment with high standards of sensitivity, introspection, and adaptability. (p. 294)

Baird continues to experiment with this methodology with the goal to eventually developing effective, independent learners who take responsibility for their own learning.

Osborne (1985) was involved in the Learning in Science Project (LISP - Primary) which was carried out from 1982-1985 in New Zealand. The goals of this research were to explore the learner's perspective of the classroom and to provide participating teachers with feedback on their science programs. Two complementary research foci were established: 1) identifying children's views of various phenomena, and 2) observing typical science lessons in order to understand the classroom experience (Tasker, & Osborne, 1983).

Tasker and Osborne (1983) used audio-recording of classroom conversation and interviews with students to elicit their views of science. However, they found that it was more difficult to collaborate with the teacher. An initial problem was to locate a primary teacher who had a real concern for primary science. This was in part due to primary teachers preferring not to teach science and minimal resources being available in the schools. Once a teacher had been identified, however, the researchers worked to establish a collegial relationship with him or her. Another problem was access to the teacher. Often the teacher simply had too many school responsibilities and discussions had to be held during other mutually agreeable times. The researchers concluded that their methodology allowed valuable insight into the learner's perspective that could influence future science curricula and teaching strategies. It also allowed for the inclusion of teacher comments which can "ensure moderation of the portrayal" (Tasker, & Osborne, 1983, p. 138).

Baird (1986) and Osborne (1985) emphasize the importance of speaking with participants as they experience science in the classroom setting. Although Osborne seems to stress the viewpoint of the learner, Baird attempts a more intensive exploration of the teacher-student interaction. However, both methodologies have the underlying theme of change. Baird is concerned with changing students and teachers into more active participators in the educational process, and Osborne is concerned with changing students' understandings of science.

Intertwined with this theme of change is another theme emphasizing practicality. Much educational research has never taken into account the context of the classroom and has been criticized by teachers as being trivial, irrelevant, and "something of no practical use to any classroom teacher" (Osborne, 1985, p. 14). By doing naturalistic classroom studies where views of the 'insiders' are consulted, authority is shared, and mutual respect is paramount, the complexity of working and learning within a classroom and school system can be portrayed. Such a portrayal is one which classroom teachers can read, understand, and consequently relate to their own classrooms.

3. Towards This Study

The research methodology that I used in this study was practical, classroom-based research, sensitive to the participants, and concerned with change. It began with a cooperative stance, but then became more collaborative because of the interest and willingness of the teacher. It would be arrogant, however, to suggest that if research is to have any value then it must adopt a qualitative, collaborative stance. Collaborative research is simply meant to address a gap between research and practice, and my use of this methodology should not suggest that other methodologies which explore additional concerns and questions cannot also inform science education.

In this study, I recognize the recency of collaborative research methods in science education, and some of the difficulties children have learning science. Therefore, the experience of attempting a collaborative methodology in a Canadian classroom, and my concomitant concerns about how children understand science combine to provide the focus of this study.

Chapter Three

Research Design

The questions addressed in this thesis deal with how a small group of children understand and construct meaning during a classroom science unit, and how collaborative research methods might be used to enhance the exploration of classroom issues. The consideration of these questions necessitated the formulation of a research design which could provide a framework in which these questions could be examined. In Chapter Two, however, the discussion about collaborative research revealed that this study was in fact a cooperative study in which collaborative methods could be used depending upon the classroom teacher's willingness to assume a collaborative role. Additionally, the previous discussion about collaboration claimed that change was inherent to collaboration, and that researchers must be willing to make compromises, and to modify initial design plans.

The research design that is presented in this chapter represents the design I developed prior to meeting with a teacher, and prior to her decision about the role she would prefer to assume in the study. As it happened, the teacher who did agree to participate in this study was willing to collaborate with me, and the subsequent modifications, and changes to this initial research design are presented in subsequent chapters.

A. Research Design Prior to Meeting With the Teacher

In this study, I anticipated that the teacher would be willing to assume a collaborative role, and that the children might display reactions to the science unit that were similar to the reactions documented by alternative framework researchers. Therefore, it was first necessary to clarify terminology and then to consider possible roles and field experiences which might address the study questions.

1. Definition of Terms

Researcher: Although collaborative methods emphasize that all participants act as researchers, the term researcher will, in this dissertation refer to me, the writer; this should not imply that other participants are not also researchers.

Scientist's Science: Generally accepted scientific viewpoint regarding any particular aspect of science [as accepted by scientists] (Osborne, Bell, & Gilbert, 1983, p. 1)

Teacher's Science: The version and interpretation of scientist's science given by the teacher in classroom presentation.

Children's Science: The views of the world and meanings for words that children tend to acquire before they are formally taught science, and offer during and after the classroom presentation of science.

2. Teacher as Collaborator

The teacher may play a key role in this study. His or her collaboration may take the form of:

1. sharing ideas about presenting science in schools,

2. exchanging ideas about children's learning in science,
3. modifying the research design,
4. reading and discussing interview transcripts and lesson descriptions,
5. reading and commenting on working copies of the thesis,
6. participating in audiotaped interviews,
7. collecting children's documents, and
8. reflecting on the experience of collaboration.

3. Student Participants

The children will assume the role of study participants, and although I plan to interview them about issues related to their personal understanding of the teacher's science, and allow them to read and respond to their own interview transcripts, they will not have access to the full range of raw data.

Upon my initial entry into the classroom, I plan to spend time talking with all the children about their science interests, and their past experiences as science students. From these conversations I intend to identify three or four children who are comfortable talking to me, and who are willing to participate in the study. In this respect, the identification of students is somewhat of a self-selection on the part of the students because my identification will be dependent on the gradual emergence of their interest in talking to an adult about science.

If the children I identify agree to participate in the study, permission letters will be sent to their parents for written approval.

4. Role of the Researcher

My role as researcher will include coordinating and guiding the study while offering the teacher the option to collaborate to the extent that he or she feels comfortable. I anticipate that my role will include:

1. observing science lessons,
2. [illegible]terviewing the teacher and the children,
3. preparing interview transcripts,
4. preparing interview summaries and interpretations,
5. discussing data with the teacher,
6. discussing the experience of collaboration with the teacher,
7. writing and sharing working copies of the study with the teacher, and
8. preparing the final study document.

5. Field Experiences

An important field consideration is the amount of time which is allotted to science in the Alberta Elementary Science Curriculum Guide (1983). At the Division II level, only 100 minutes per week is recommended, an allotment that would provide me only 2 or 3 periods of class time per week. In an attempt to expand my time, provide me with a broader view of the classroom situation, and to help me appear as less of a 'stranger' to the children, I will be sitting in on other subject areas which precede, and follow the science periods. Not only will this allow me an increased time for getting to know the children, it will also provide me with a sense of the classroom events taking place which may influence interactions during the science period.

The procedural activities I intend to use in the study are presented in the following sections.

a) Study Summary

A research proposal summary will be used to guide the discussion during my initial meeting with the teacher. This summary will take the form of an outline presenting (a) the purposes of the study, (b) anticipated methodology, (c) a description of collaboration, (d) potential student interview questions, and (e) the teacher's potential role in the study. [see Appendix A]

b) Ethnographic Recording of Classroom Description

My written records will include field notes of the physical description of the classroom and my observations of each science lesson. Descriptions and observations will be organized, typed, and shared with the teacher for consideration and comment. [see Appendix B]

c) Group Interviews With the Children

I will begin by audiotaping two or three group interviews in which I expect I will have to spend some time explaining to the children why I am in their classroom, what I am going to do, and why they are being asked to be key informants. It will also give the children an opportunity to get comfortable with the idea of talking to me, and being tape recorded before moving into individual interviews. At the conclusion of the study, the children will participate in a final group interview in which their general comments about science, and the study, will be explored.

d) Individual Interviews With the Children

Prior to the presentation of the science unit, I intend to interview the teacher about her plans for the unit. From this interview, I will generate a list of questions about this unit and then interview each child on audiotape to ascertain his or her initial ideas about the science topic. [see Appendix C]

After each lesson in the science unit, the students will be interviewed on audiotape to elicit their reactions to the lesson, their ideas about the teacher's science, their method of coping with the tasks, and their questions about the lesson. [see Appendix D]

e) Summaries of Children's Interviews

A brief summary and interpretation will be compiled from the children's individual interview transcripts. Each child will have the opportunity to read and comment on the accuracy of the summaries. [see Appendix E]

f) Teacher Interviews

The teacher's initial ideas about teaching and learning will be explored during an audiotaped interview which will be carried out prior to the commencement of this study. We will also discuss the curriculum as planned, and the teacher's personal philosophy and values as they apply to science.

After each science lesson, the teacher will be interviewed about the difficulties experienced, and his or her perceptions of student learning during the lesson.

The teacher will also be asked to record any reflections on our discussion that may seem pertinent, and any observations of the key informants in other subject areas which may stand to influence their actions in science.

g) Daily Journal

This journal will contain the personal side of my fieldwork and will include reactions to informants and classroom observations in addition to my reflections on my experience of collaboration. I will not make the contents of this journal available to other research participants.

6. Data Analysis

The list of questions which the children will respond to after each science lesson provides the broad framework against which data analysis will occur. These questions are designed to explore the children's perceptions of (a) the purpose of the lesson, (b) how they coped with the lesson, (c) what they learned and understood about the lesson, (d) what they believed about the lesson, (e) how their ideas changed, (f) how the lesson might be related to other lessons, (g) new vocabulary, and (h) what they wondered about at the conclusion of the lesson. The children's answers to these questions will be compiled into interview summaries, and will be examined against my written descriptions of the content, action, and dialogue of the science lesson. I will make brief interpretations of emerging themes and these interpretations will be submitted to the children and teacher so that they may read these interpretations, assess the accuracy of my comments, and add their interpretations to mine. In this way, data analysis, and the validity and realiability of the interpretations, becomes, to some extent, a collaborative analysis in which the ongoing process of investigation and collaboration results in an accurate description of the situation, followed by interpretations which portray the ideas and experiences of the participants. The readers, too, will participate in the determination of validity "to the extent that the observations cover some matters that they are already familiar with" (Stake, & Easley, 1978, p. C:27).

My decision to share the data with the teacher, and to include the teacher and the children in data analysis, was based upon the realization that it was absurd to claim that the study involved collaborative methods if the teacher was to be prevented from reading and reacting to the majority of the data. Be that as it may, sharing data with participants stood to influence what data would eventually be included in the thesis, what comments I might choose to record in my classroom notes, and what comments might be edited from the children's interview transcripts. These concerns about the potential effects of sharing data gave rise to the question, How can the study be a reliable and valid portrayal of the situation if participants have the opportunity to read and perhaps edit the study before it is made public?

First, when a teacher agrees to participate in a study this does not give the researcher "license to reject any responsibility" towards the participants (Glazer, 1972, p. 134). In all research studies, and perhaps especially in classroom-based studies, the researcher should carefully weigh his or her own interests against the lives of the participants. If a critical decision arises, then the researcher should err on the side of ethics and compassion toward the participants.

Also, all observations and conversations gathered during a qualitative study rarely appear in the final draft of a thesis.

Some data simply does not inform the study questions. Other comments may be uttered in confidence and their appearance in a public document constitutes a breach of that confidence. Therefore, the data which appear in the final document always represents only part of the entire picture, and if this document is judged by study participants to be an honest portrayal of what it does discuss, then it is valid. Perhaps we can conclude that the decision to share the data with participants, and to exclude some data from the written thesis, is not a question of honesty or validity, but an expression of the compassion and responsibility that must exist towards those who are willing to assume the burden of allowing researchers into their classroom.

The small number of children in this study limits generalizability in the traditional sense. Instead, generalizability depends on the degree to which the reader can relate to what is described, remove it from context, and interpret it in terms of his or her own life experiences. Stake and Easley (1978) speak of the naturalistic generalizability of their qualitative studies.

> We looked for a kind of generalizability based on deep understanding of phenomena which increases one's opportunity to recognize similarity and analogy. [Generalizability] depends on extending the reader's existing apprehension of experiences through new vicarious experience. The general then is a very personal general. (p. C:26)

In this way, if student comments, and our discussion and interpretation of those comments, can be translated to the reader's situation and can result in an extension of understanding, then generalization has occurred. The value to educators of this kind of generalizability is that the readers are part of the decision-making process and will be able to make a personal judgement about the utility of the study.

B. Towards This Study

The research design presented in this chapter represents the plans made prior to locating a classroom and participants. In the remaining chapters, this design is changed and modified by the teacher's willingness to collaborate, the time restrictions we experiences, the content of the science unit, the teacher's illness, and the need to make the study compatible with the existing classroom timetable. Specifically, there were changes and modifications to my initial plans for (a) choosing the children, (b) introducing the study to the children, (c) observing other subject areas, (d) the initial group interviews, (e) the children reading and responding to the interview summaries, (f) the number and format of the teacher interviews, and (g) audiotaping children's dialogue during science lessons. Some of these changes and modifications are discussed in subsequent chapters while others, such as my plans to observe other subject areas, are not discussed because they were simply dropped because of time restrictions, and the teacher's willingness to share her insight into the children's personalities, and homelives.

In the following chapter, I begin my search for a Division II classroom in which science is taught on a regular basis, and for a teacher who might be willing not only to allow me to intrude into the classroom, but who also might be willing to assume a collaborative role in this study.

Chapter Four

Research Setting

The decision to explore my study questions by using methods associated with collaborative research necessitated identifying both a teacher who would be willing to undertake considerable responsibility, and a group of children to which I could direct my attention.

A. Choosing the Classroom

An application providing a description of the research was sent to the central office of a large, urban school system. This application requested a Division II classroom in which elementary science was taught on a regular basis by a teacher who might be willing to participate in ongoing collaboration.

I requested a Division II classroom for this study for two reasons. Division II students would probably have a larger vocabulary and a higher level of articulation than Division I students, and this could be helpful in interview situations. Also, Division II students have had more experience in elementary school science and thus are likely to have a wider perspective and variety of background experiences which may stand to influence how they approach the science unit.

The aspect of my application about which I was most hesitant was locating a teacher who would be willing to allow this study in his or her classroom. Although I felt confident that activity science classrooms did exist in this school system, I wondered if there was a teacher who would welcome a researcher who not only expected to observe all the science classes, but also wanted the teacher's ongoing input into the study. These feelings of doubt were intensified by the knowledge that I had never worked within this school system and was not familiar with any staff members that I could independently contact, and to whom I could propose the study.

Consequently, I requested the assistance of one of the school system's science consultants and asked her to recommend a list of Division II teachers who were interested in elementary science education, were known to have an activity science program in their classroom, were personable and capable of carrying out a collaborative effort, and who possibly had attended the consultant's recent inservice presentation on alternative framework research. The consultant provided a list of 15 teachers whom she thought might be appropriate for this study.

1. Contacting the Teacher

Prior to contacting any of the teachers on the consultant's list, I decided that I would phone a teacher, meet with him or her, and allow him or her to make a decision about participation before I would contact a second teacher. This method was used to avoid the situation where I might initially speak to several teachers, have more than one agree to participate, and then be faced with having to make a choice among these teachers. One disadvantage of this approach was that it could use considerable time, especially if I had to contact many teachers and allow each of them several days to consider the project. As it turned out, I only had to talk to two of the teachers on the consultant's list before one agreed to participate.

The initial phone call to the teacher held many challenges. I realized that I would appear as a stranger and in retrospect, I believe I should have had the consultant do the initial contact so that the study would immediately be legitimized, and the teacher forewarned that she or he was to receive a call from a doctoral student. The teacher who did agree to collaborate with the study remarked in subsequent interviews that the initial phone call did seem to come "out of the blue" and that despite my brief introduction to the study and what it potentially entailed, she was not sure just what I was asking of her. Regardless of her uncertainty about the study, a teacher who shall be called Mrs. L agreed to meet and talk with me about her potential participation in the study.

2. Initial Meeting With the Teacher

On October 16, I had my initial meeting with Mrs. L, the grade four teacher who eventually agreed to collaborate with this study. The purpose of this meeting was to introduce myself, inform her of the nature of this study, give her a written copy of a summary of the study [see Appendix A] and to ask her to contact me when she had arrived at a decision regarding participation.

My overwhelming concern was that I was simply asking for too much; I felt that there was a possibility that I would be unable to find a teacher who would be willing to work on this study. This concern was reflected in the journal notes I wrote about this initial meeting.

> I enter the school at 3:25 p.m. and go into the General Office. There is no one at the secretary's desk and the principal's office is dark. As the teacher has said that she will find me at about 3:30 p.m., I stroll into the hallway and read the various notices that hang from two bulletin boards: community events, and a school philosophy statement.
>
> Small children are milling about in the hallway and several parents stand in the hall with me seemingly waiting for children. Several of the adults glance towards me and I fell a bit awkward. At 3:32 p.m. a parent approaches me and asks if I am looking for someone as 'I don't appear to be one of the regulars'. I mention the name of the teacher I am seeking and the parent guides me to the doorway of the correct classroom. The teacher spots me, we introduce ourselves, and then the teacher introduces me to my parent guide.
>
> I am nervous as thoughts of just how much I am asking of this teacher weighs on my conscience. I wonder if whether our situation were reversed, I would even agree to participate in this study.

I began our meeting by asking the teacher if I could audiotape this initial meeting because if she did agree to participate, it would be important for us to be able to have a record of the content of the interview. The teacher seemed hesitant so I assured her that once the interview was completed, the tape would remain in her possession. I added that if she agreed to participate, I would require the tape for transcribing. Later, the teacher confessed that being audiotaped was an intimidating and somewhat disconcerting experience, but at the same time she realized that the tape could contain data important to the study.

The interview began with my description of how I arrived at my study questions. Then, I defined collaboration and offered that collaboration could possibly involve: teacher input into study design, the teacher reading interview transcripts, ongoing interviews with the teacher, and sharing the eventual thesis write-up. Next, I informed the teacher that the methodology would involve audiotaping interviews with the children and the teacher, and recording written descriptions of the science lessons. I further encouraged the teacher to take advantage of the flexibility of the study design and to consider providing ongoing comments about practical concerns, and philosophical issues. Finally, we discussed briefly the potential timeline of the study, the choosing of student participants, and the written summary of the proposed study that I had brought with me. Later, Mrs. L wrote:

> When you outlined your research proposal I found myself considering very carefully whether grade four students could withstand the steady interviewing. You helped me to make this decision by giving me several examples of the types of questions you would ask the children. The questions were straightforward enough and I suspected the children would enjoy the experience.

The teacher had many concerns and comments about her potential participation in the study. Her first concern was regarding the many other commitments in her life. She was already involved in a Learning Processes inservice program concerning children's learning styles. She also attended science inservices and had impending responsibilities with respect to a student teacher, and the Christmas Concert.

Mrs. L also predicted that the presence of a researcher in her classroom could add to existing stress levels. She thought she would feel "on display", and that this could probably lead to a sense of vulnerability.

Mrs. L was also concerned that the study might become an evaluation of the teacher. This was an issue which arose during my master's thesis, and I hoped that by including Mrs. L in the data collection, sharing transcripts with her, and maintaining an ongoing discussion, would relieve her concerns. Osborne and Freyberg (1985) warn that

> Teachers who expose their classes to this kind of observation must be assured that their performance _as teachers_ is in no way being judged, although it is inevitable that what they say to their students, individually or as a class, will affect the thinking and responses of those students. (p. 161)

The teacher added that she was familiar with talking about her teaching because of her past involvement in an _Effective Teaching Program_, and she was already aware that children were capable of making critical comments about their school experience.

Another concern centered on the fact that another teacher in the school was vocal about her own negative experience regarding the presence of a graduate student researcher in her classroom. Mrs. L, however, felt somewhat reassured that her own experience might be positive because of the potential to share the data and collaborate with me.

We also discussed the potential scheduling and timetabling of the study. Mrs. L wondered if she taught "enough" science, whether her classes would fit into my schedule, and when I hoped to complete my study. I emphasized that I would fit my schedule into her timetable and that her next science unit on _Sound_ would probably be of a length quite suitable to this study.

When this initial interview ended, I asked the teacher to contact me when she had made her decision about participation. Although I thought that both the teacher and her program would be ideal for the study, I really felt that she would decline to participate. Later in the study, Mrs. L wrote:

> I realize I must have sounded awfully cautious, even negative. But, I was actually excited and wanted to do the project right from your first call - I was just building up my nerve, I guess.
>
> Really I was quite excited by the prospect. I just wondered: What did you expect of me?, and Could I live up to it?

On Sunday, October 18, Mrs. L phoned to say that she would be willing to participate in the study. She suggested that I come to her classroom during the morning of October 19 so that she could introduce me to the children, and so that I could start to familiarize myself with the classroom.

3. Entering the Classroom

I entered the classroom just prior to the morning bell and two students immediately asked me if I was a substitute teacher. Mrs. L soon introduced me as someone who was interested in elementary science, and who would be observing the lessons and talking to children during science class. The children seemed accepting of the idea of having another adult in the classroom and they spent the rest of the period silent reading, writing a spelling test, and compiling lists of questions that pertained to the magnetism unit they had just completed in science. I spoke to several children about their magnet questions and then departed from the school after the morning recess.

On October 20, I met at noon with the teacher and the principal. Rough drafts of the two student permission letters [see Appendixes F and G] were presented for their approval and I agreed to make some minor changes.

After our meeting with the principal, the teacher and I went to her classroom and spent 15 minutes introducing the impending study to her students. Although I had originally planned to do this introduction, the teacher believed that the children would be more accepting of the research if they could observe that the teacher was also involved and supportive of the study. At the time, Mrs. L was not aware of my intentions to introduce the study, but because I valued her willingness to become involved, and the thoughtfulness of her action, I encouraged her to do the introduction. Consequently, Mrs. L told the children that

1. I was working on a Ph.D. and was interested in children's learning in science;
2. I would be coming to the children's science classes to observe the science activities, to talk briefly to many children, and then to spend time interviewing a small group of children using a tape recorder;
3. the children who would be selected for interviewing would have to be committed to attending the interviews and being responsible; and, that
4. tomorrow, a letter would be sent home to explain the study to their parents.

Upon hearing this introduction from their teacher, the children directed some questions towards the teacher and me. Some of these questions included:

1. Will anyone be hearing the taped conversations?
2. What if we don't know the answers?
3. If we have the wrong answers, will you tell us the right answers?
4. Will we be missing class to do this?
5. Will there be any homework if we miss class to be interviewed?

After we answered these questions, Mrs. L asked the children to think carefully, and then to raise their hands if they thought they would like to be in the small group that would be interviewed. Twenty-two of the twenty-six children in the class raised their hands.

B. Choosing the Children

On October 21, general permission letters were distributed to all the students in the classroom. Two students were eager to know if all the children could be interviewed and I answered that although I was interested in what all of them had to say, time prevented me from such an extensive exploration.

Although I had originally intended the selection of the children to be more of a self-selection, the time spent attaining approval from the school system and gaining entry to a classroom influenced the time available for the students to participate in a self-selection. Therefore, the teacher and I met after school to generate a short list of possible candidates for the interview sessions. Issues which influenced our choice of child participants included:

1. excluding the four children who did not raise their hands;
2. recognizing that some children were already doing something 'special' such as Academic Challenge, although they would be good participants;
3. desiring both male and female participants;
4. predicting which children would not be intimidated by an interview situation;
5. considering the emotional needs of children, and asking ourselves who would benefit from extra attention;
6. considering who would be responsible, persistent, and committed;

7. wondering which children had a good voice for audiotaping; and
8. wishing to involve children from a variety of ability levels.

The teacher and I discussed these issues and on October 22 Mrs. L supplied me with a list of approximately ten students who would be appropriate for the study. During the science class that took place that same day, I assessed how comfortable these students were with me by talking with them as they worked at their desks. From these conversations, I selected five students who subsequently agreed to take part in the interviews. These five were given a second permission letter which outlined their additional responsibilities. The pseudonyms that the children chose for themselves were Christa, Victoria, Bob, Gordon, and Samantha.

C. The Setting

Greenwood School is located in a large, urban area. The school is surrounded on four sides by middle and upper class housing; a university housing complex for married or mature students is situated several blocks from the school. About 50% of the children in the school live in this housing complex. Consequently, the school population represents a wide spectrum of socioeconomic groups, contains children of many different ethnic origins, and consists of many children who have parents involved in undergraduate and graduate programs.

Mrs. L's grade four classroom is situated on the north side of the school immediately adjacent to the grade five classroom. She has 26 students in her homeroom and 12 of these students live in the university housing complex. Five students who live outside the housing complex also have parents enrolled in university. About 54% of the children in Mrs. L's class are from Alberta. The remaining students list Ontario, Quebec, Brazil, Iran, Hungary, Zambia, and the United States as their birthplaces. Mrs. L has noticed that parents of students from outside Canada have an especially high regard for mathematics and science, and they consider these subjects to be of prime importance, even at the elementary level.

The Grade Four classroom has two sinks along the east wall which, although useful to the teacher, are situated in a shelving unit that renders them too high for the children to use comfortably. Storage shelves and bookshelves line the room and Mrs. L is able to store some of her science equipment inside these units. The two windows are bordered with bulletin boards which display an assortment of children's projects, a list of French vocabulary, a relief map of Alberta, wildlife posters, and a collection of items about Sound. These Sound items include: magazine articles on lightning, bats, planes, and dolphins; directions for taping sounds on a tape recorder; directions for constructing Dr. Zed's Elephant Whistle; and a chart illustrating symbols used in sign language.

In the northeast corner of the classroom is a small corner display with a variety of books, some of which are about various science topics including Sound. A gerbil cage containing three gerbils is located near the southeast corner of the room, and a projection screen hangs from the ceiling on the west side of the room.

The classroom is constructed from a variety of acoustic materials. The floor is covered by broadloom, acoustic tiles line the ceiling, and the walls of the classroom have a textured appearance.

The children sit in groups of four or five and their desks have flat tops that are ideal for working with objects that would roll off an angled surface. The chairs are separate from the desks and are easily moved to new seating arrangements.

Mrs. L's classroom gives the general impression of being bright due to the lighting, windows, and color scheme. The large displays of children's work and the provision of special items which children can observe and read, combine to suggest that children, and their ideas, are both valued and encouraged in this classroom.

D. The Teacher

Mrs. L teaches all subjects to her students except for mathematics and physical education. For these subjects, she switches classes with the grade five teacher. Additionally, Mrs. L teaches music, art, and Extended French to her own class, and also to Grade Five.

Mrs. L is in her fifth year of teaching. In the early 1960's she attained a Bachelor of Arts degree with a double major in English Literature, and zoology. During this time, she also took a number of additional science and math courses and then assumed responsibility for raising her young family. In 1978 she re-entered the Univeristy of Alberta in a B.Ed./A.D. program and completed the program requirements by 1981. She was soon hired for an elementary position with the system within which she is presently employed.

Mrs. L is enthusiastic about science as a subject area and has served as a Division II representative on the provincial science teachers' specialist council. She attends inservices in elementary science, and subscribes to science publications such as Science and Children.

Mrs. L describes her science program as being activity-based; involving the children in working independently and with others; including the process skills; requiring some written records in children's notebooks; containing other experiences such as field trips, films, guest speakers, and library research; and involving times when she has to tell the children some information. She thinks it is important for teachers to display enthusiasm and interest in science, and describes herself as an interpreter, resource person, mentor, and guide for the children. Her experience has taught her that children enjoy an activity program and gain confidence when they are able to explore and manipulate materials at their own pace. She wonders if girls need extra time in science because they frequently lack the knowledge and experience that would benefit them during some science topics.

Although Mrs. L enjoys teaching science, she also recognizes that it is a challenge to cope with an activity program. It takes time to plan the activities and locate materials for class use. The science period must also fit into the timetable and sometimes this restricts the amount of time available for the children to manipulate objects independently. Additionally, Mrs. L has the children sitting in groups to encourage them to share materials and exchange ideas, but she admits that this arrangement may present problems especially when she requires the students' attention. She has also observed that children seem anxious about evaluation, however, some form of evaluation is required by the school system in the form of a report card mark.

In general, Mrs. L believes that science should be taught in elementary grades and that children benefit from their involvement in science. However, such factors as time, the availability of materials, class size, budget cuts, and increasing teacher responsibilities, all stand to influence how teachers approach and present science in the classroom.

In addition to Mrs. L's responsibilities as an elementary teacher was the commitment she made when she volunteered to participate in this study. Her willingness to collaborate with me meant that her crowded schedule had to be modified to include times for reading transcripts, being interviewed, and reflecting on the study. The experience of this collaboration, and how it influenced the study and ourselves is presented in the following chapter.

Chapter Five

Experience of Collaboration

During our initial meeting, I provided the teacher with a summary which outlined some of the main themes of collaborative research recognized by other authors (Amabile, & Stubbs, 1982b; Hord, 1986; Trubowitz, 1986). These themes included the necessity for mutual respect, the recognition that each participant brought specialized knowledge to the study, and the anticipation that there could possibly be a gradual evolution of the research methodology.

As the study progressed, Mrs. L and I discussed how participation in a collaborative study, and the sharing of data, was influencing both ourselves and the study. We also examined questions about the requirements of collaborative methodologies, and what we eventually perceived to be the costs and benefits of these methodologies.

The study changed both the teacher and me, and although the children did not articulate it to a great extent, it can be implied from their comments that the study also caused the children to reflect more upon their actions and thinking.

This chapter will focus on the experience of collaboration that was created by the teacher, the children, and myself and how collaboration served to expose the requirements, dilemmas, limitations, costs, and benefits of this methodology.

A. Requirements of Collaboration

In this study, the teacher and I were aware of the roles that the participants' personalities and philosophies could play in a collaborative study. It seemed that collaboration might not occur unless both the teacher and the researcher possessed certain personality traits, and particular attitudes toward research. Therefore, part of our experience of collaboration involved the identification of these traits, and subsequent characterization of potential collaborators.

I commented that a teacher who is recommended for a research study probably already has the reputation for 'going beyond' the job description. This suggests that the teacher who is judged to be exceptional within the school system is asked to assume even more responsibility. Consequently, the teacher who might agree to participate is one whose desire to learn and grow outweighs his or her reservations about time and extra work.

Mrs. L wrote that the potential teacher-collaborator should be interested in the theory behind the practice of teaching, and perhaps might already have questions about classrooms that he or she lacks the time and expertise to research independently.

> A teacher who is supportive of classroom-based research by university researchers may be the kind of person who has sometimes wondered why certain things happen in [her] own classroom, and whether certain things could be found out. Such a person would be more likely to be interested in an outsider's project in [her] class.

Mrs. L thought that prior to agreeing to participate in collaborative research, the teacher should be willing to make the commitment to work closely with someone, and should be inclined to assume responsibility to see the research through growth stages to completion. This suggests a considerable time commitment;

Amabile and Stubbs (1982b) offer that "before teachers decide to become involved in research, they must realize that the time commitment may be substantial" (p. 249).

In addition to recognizing the time commitment involved in a collaborative study, the teacher should be willing to cope with scheduling changes which might arise from the necessity for the researcher to observe a class in progress, and to interview the children after the conclusion of that class. Perhaps a teacher who is adaptable, flexible, and responsible for the same children for large blocks of time might be best able to adapt to these scheduling adjustments.

Ideally, the university researcher should possess past experiences that are in common with the teacher. In this study, our shared experience as elementary teachers helped us immediately to converse on a common topic, and my background provided me with additional insight into the challenges Mrs. L faced presenting science in an elementary classroom.

The researcher should also realize that change is inevitably a part of the collaborative process. Changes may arise in the form of (a) scheduling alterations, (b) methodological modifications, and (c) editorial comments submitted by the teacher. This suggests that for collaboration to occur, the researcher must be flexible, sensitive, and willing to make compromises.

Collaborative research can only develop in an atmosphere of dispersed leadership. Amabile and Stubbs (1982b) maintain that "regardless of who initiates a research project, researchers who decide to collaborate with teachers on research should attempt to make that collaboration as complete as possible" (p. 251). In this study, I invited the teacher to participate in analyzing and interpreting the data, in editing working copies of the thesis, and in offering insight into her experience of the study. During her final interview, Mrs. L commented:

> I asked myself, 'What did you mean by collaboration?'. I guess you meant handing me transcripts and keeping me informed. You also asked me for any input I might be interested in offering. And you were very careful to make it clear that nothing was pressed. I never felt pressed to have input of any kind.

Reciprocity is an issue which should be given due consideration in collaborative research. The researcher must be aware of the teacher's potential responsibilities concerning data collection, interviews, and editing manuscripts. De Bevoise (1986) recommends that "the first step in a collaborative project is to appreciate what the rewards are for each side" (p. 11). This suggests that the researcher should value the insight the teacher possesses, and should "consider whether the customary expression of thanks is really enough compensation and should attempt to provide something more tangible" (Amabile, & Stubbs, 1982b), p. 252).

In summary, the teacher and researcher should be flexible and confident, and should possess a mutual respect for the insights each has "to offer to both understanding children and doing research" (Amabile, & Stubbs, 1982b, p. 248). Time is a major consideration in collaborative research, and participants should be aware of the constraints which may serve to restrict the actions of others. The researcher and the teacher should ideally possess some common background experiences, and the initial sharing of these experiences can potentially create a foundation upon which future sharing and cooperation can occur. Finally, the researcher should be cognizant of the potential contributions of the teacher, and should strive to ensure that the teacher receives some form of compensation for his or her time and effort.

B. The Influence of Collaboration

During the study, Mrs. L and I worked together to develop and modify the research methodology that I initially presented to her. Our modifications arose from our concern to adapt the methodology to the children, and to the classroom presentation of Sound. Additionally, our collaboration influenced the data I chose to include in this thesis, and resulted in a recognition that we had all been influenced by the experience of collaboration. Issues involving the influence collaboration had on the study, the teacher, the children, and on me are presented in the following sections.

1. On the Study

The collaboration between Mrs. L and I resulted in minor changes to the intended methodology. Some changes were mentioned in Chapters Three and Four and these involved the method of choosing the children for the interviews, and the introduction of the study to the class.

Another change to the intended methodology involved the children's interviews. Initially, the children were to spend part of their interviews reading and reacting to the interview summaries. My interview questions about each lesson were of such length, however, that little time remained to reflect on summaries from previous interviews. Therefore, I had to modify my plans to ensure that this important aspect of study validation was not omitted, and some of these modifications included (a) paraphrasing and interpreting the children's responses, then asking the children for their reaction to my interpretations; (b) bringing interview summaries to each interview for the purpose of referring to specific comments already offered about a concept; and, (c) including a summary interview in which previous statements were examined and sometimes challenged.

I also found it impossible to audiotape the children's comments as they worked on their science activities in the classroom. First, the activity times tended to be about five to ten minutes in length, and usually the children only had time to repeat the teacher's demonstration, briefly try some of their own ideas, and then continue with a teacher-directed class discussion. During these activity times, the children seemed to prefer to work at the task rather than respond to my questions. When I would attempt to interrupt these children to clarify what they were doing and thinking, they tended to stop the activity, speak with me, and consequently not finish the task. Second, the Sound unit contained many activities in which the children made and explored sounds. This resulted in my tape recorder being overwhelmed by background noise even when I used an external lapel microphone.

In response to my inability to record the children's science experiences 'in progress', I spent time writing brief anecdotal records about the five children participants as they participated in the activity. Also, I tried to interview all five children on the same day as the activity and I hoped this would enhance their recall of the lesson.

Another change to the intended methodology was prompted by the teacher's health. Following her first lesson about Sound on October 27, Mrs. L fell ill and was unable to return to the class until November 9. This event emphasized the human element of classroom studies, and, in part, exposed the high degree of responsibility that Mrs. L felt towards this study. During Mrs. L's illness, I was able to interview the children regarding their perception of learning, understanding, and believing. The children's comments were to form a starting point for this study and are presented in Chapter Seven. Although participant illness obviously is not a requirement of collaborative research, it did provide the teacher and me with time to share our thoughts, to gain insight into our roles as educators, and to establish a working relationship that perhaps was strengthened through this adversity. Perhaps this experience suggests the value of incorporating increased time for reflection and sharing following the initial agreement to collaborate, and prior to the commencement of data gathering.

In this study, Mrs. L read the children's interview transcripts and encouraged me to include all of the children's comments regardless of how the comments might reflect on herself or her teaching. As it transpired, the children were positive about their science experiences and concerns about omitting some of their comments never arose. Mrs. L also thought that I should record episodes of classroom discipline and management which I intentionally omitted from my observation notes. She believed that these events must also influence how children learn science, and although I agreed with her, I felt that the inclusion of these descriptions might make the study appear more as a teacher evaluation than an exploration into children's learning. Also, information collected from interviewing the children was more critical for answering the study questions, and the classroom descriptions served more as a background against which the children's words could be portrayed.

Data sharing also added to the time spent transcribing audiotaped interviews. In a cooperative study in which data might not be shared, the researcher can make brief notes directly from the audiotapes, and forego complete transcripts. In a collaborative study, formal transcripts should be produced to ensure that the teacher is informed and knowledgeable about what is transpiring.

2. On the Teacher

Mrs. L wrote and spoke at length about her experience of participating in this collaborative study. Specifically, she identified my observation of her lessons and her opportunity to read the children's interview transcripts as prominent factors.

During my observation of her science lessons, Mrs. L felt more aware of her actions, lesson presentation, questioning techniques, speech habits, and her classroom management. She felt constantly on display and it wasn't until November 17 that she spoke of feeling more relaxed.

> I was ill at ease. It bothered me. I was annoyed and exasperated that I could not overcome my nervousness faster. I anticipated that I might be [nervous] when I agreed [to participate], I guess.
>
> I don't know why I was ill at ease because I have had a lot of these consultants come in and . . . I seem to perform quite comfortably in front of them. Maybe it is because they only come now and then.
>
> So, I thought 'Well, let's see, the more science I do for awhile [the more I'll get used to you and then] I won't even care'. That's the week that we wore each other out. But, I got over [my nervousness] you see, because I taught science nearly every day and I couldn't have cared less by the end of the week about whether there were 27 science researchers at the back of the room.

My observation of Mrs. L's lessons, and her reading of the interview transcripts, influenced Mrs. L to reflect upon her current methods of student evaluation.

> I have also thought a little harder about how I was evaluating them and what different ways [there are] to evaluate what has gone on. We are always confronted by the fact that we have to come up with a report card mark . . . it would perhaps be a good idea to see if there's a different way besides knowledge-based or problem-based written evaluations.

Mrs. L described the children's interview transcripts as "fascinating", "informative", and "insightful." The transcripts changed her experience of teaching the unit and she also began to question come of her present practices, and wonder about the children's experience of her science lessons.

> I was fascinated to see what they were thinking, how much they knew, and how clearly and confidently they could articulate their thoughts. Just to think - while I am conducting lessons and activities . . . these children are sitting there entertaining such interesting, complex, and down-to-earth thoughts, weighing and judging information and tossing out the stuff that sounds unreasonable.
>
> To read about what they have been thinking in class as the lessons roll along is like looking into a new world - perhaps like jumping in with a mask to see the fish after just basking above on the ocean surface imagining what they looked like.

Mrs. L also commented that being observed and reading the children's transcripts influenced her approach to planning the lessons, her personal evaluation of her lessons, and her response to the children.

> I have already acknowledged that I think, plan, and prepare more carefully because of the presence of an observer. For upcoming lessons, [I ask myself], 'Should I modify, leave out, or plan differently knowing better what tasks they feel successful at and where they felt they learned something?
>
> For lessons already completed - in the future, 'How could I make those concepts more clear to grade four? Is it possible even? What increased learning steps or real experiences can I create? Your summary headings help me to evaluate the lessons in terms of their perceived learning and understanding. [For example], the lessons where they thought they clearly learned something stand out from lessons where they felt confused about an objective. So I think, 'Shall I build in more about the concept in upcoming lessons? How [can I] re-teach it more meaningfully?'.
>
> As I am thinking about the Sound unit, I sometimes look up what the children thought about some concept (e.g., what did they seem to know about echoes, or matter) - to see if I can make a meaningful link between those early impressions and what I would like them to know about the concept after some activities and lessons.
>
> I feel an increased sensitivity to, or awareness of, the student's viewpoint. They are waiting for a task to be set. How clearly can I do this?
>
> Already, sometimes, while I'm teaching, I look out at the silent, expectant faces in the class and I can almost hear the transcript voices wrestling with something I've just said - those unearthly, sensible, logical children's thoughts.

At the conclusion of the study, Mrs. L made additional comments about how reading the transcripts not only changed her during the study, but how the children's comments now stood to influence her science teaching during the remainder of the year. Some of these summary comments refer to specific quotations that the children made and others to science activities that took place during the unit. These additional comments will be integrated into Chapters Six, Seven, and Eight where they can appear within the context to which they are referring.

3. On the Children

It was more difficult to ascertain what influence a collaborative methodology was having on the children. Perhaps this was due to the fact that they had more of a cooperative stance, and only read and responded to data gathered during their own interviews. Therefore, their comments about participating in the study do not represent their experience of collaboration, but only portray their experience of being observed during science class, and being interviewed by a researcher.

Christa remarked that in general the study left her with a good feeling but that it was hard to describe this feeling. She did say, however, that

> C: [The interviews] get me to think back to the lesson and remember it and it stays in my mind a little longer than the other [subject area lessons].

She added that my classroom observation did not affect her participation, and that she was only aware of my presence when she sought me out to show me some of her Sound activities. Christa had not mentioned the interviews to her parents, and as they had forgotten about her involvement, they were unable to comment about their daughter's reaction to the study. Mrs. L added that, in her opinion, Christa displayed greater participation and interest in science class than she did prior to the study.

Victoria enjoyed the interviews because

> V: I like just talking. I talk a lot.

Victoria's mother volunteered that her daughter was thrilled to be participating in the study and that Victoria talked about it on many occasions at home. She felt that Victoria was pleased and flattered that someone wanted to hear what she had to say about science. Mrs. L observed that Victoria seemed to pursue classroom questions in a more persistent manner as the study progressed. Victoria seemed to increasingly question the teacher, and Victoria compiled written notes which she used during some interviews.

Gordon remarked that interviews were a good experience for him, and that he could not think of anything that seemed negative. He stated that my presence in the classroom and his anticipation of the interviews did not affect him in any way. Gordon's mother commented that Gordon "loved" being involved in the study, talked about the study at home, and found it interesting to talk to someone about a subject in which he was interested.

Bob spoke of this study only in a positive manner. He talked about how the interviews helped him to understand Sound, and how interviews would probably assist him in getting better in science. He added that

> B: It makes me remember in my mind and it helps me more in science and stuff.

Samantha commented that the interviews helped her because they

> S: Make my brain think more. That is good to make your brain think.

She added that

> S: Sometimes [the teacher] asks me a question and then someone tells me I have to go with you and I figure out the answer better.

Samantha found it interesting to view her initial ideas about sound although she admitted that her ideas did not seem to show much change. In class, she thought that my presence influenced her to think "harder", and to listen more carefully because she wanted to give me the 'right' answers. Samantha's parents had heard a great deal about the study from Samantha at the commencement of the study. Since that time, they could not recall Samantha commenting about the study but reasoned that they both worked and discussion time was limited. However, they did believe that, in general, Samantha was very pleased with school.

4. On the Researcher

Participating in collaborative research increased my sense of responsibility and accountability towards the children, the teacher, and the science consultant who made the initial recommendation of potential teacher participants. Before Mrs. L agreed to participate in the study I wrote:

> One of the main concerns that I have at the commencement of this study is the responsibility towards the participants. I am very much aware that I am representing the university, and educational research, to the cooperating teacher and school, . . . I also feel some responsibility to show the school staff that not all graduate research is carried out [in the way a previous study was performed at that school. In this previous study, the graduate student failed to communicate with the teacher].
>
> I am also aware of a responsibility towards the science consultant. I suspect that the consultant recommended people who had an activity science program and who she might consider to be her friends. Therefore, I do not want to make this a 'bad' experience for the teacher nor would I want the consultant to regret she involved the teacher in the study.

With these responsibilities in mind, I hoped that by making the study a flexible, open experience to both the teacher and the children, the benefits of participation would outweigh the costs. These concerns also made me more aware of the importance of reciprocity and, as I observed the amount of time and effort that the participants contributed to the study, it was obvious this was a significant issue.

My awareness that the teacher would be reading the children's transcripts made me more sensitive to how the teacher might react to comments the children might make about her teaching and classroom management. As it happened, the children were very positive about both the teacher and her presentation of the science, and the issue never arose.

My classroom observation of the science lessons impressed upon me the extent and number of the very practical, daily events which are inevitably a part of teaching science in school. It reminded me of my own experience as an elementary school teacher, and made me question the present content and format of undergraduate courses in elementary science methods.

My experience of collaboration made me increasingly humble about my knowledge of elementary science, and made me more aware of how my own elementary students had experienced my science teaching. The design of the study and the conversations that took place made me aware of the personal experience of learning that each child seemed to undergo, and both the teacher and I wondered if teachers have as great an influence on children's learning as might be assumed. Towards the beginning of the study I wrote:

> I think we both wonder if teachers have the influence on children's learning that society tends to think [teachers] have. At this point, I am leaning towards the idea that not only is children's learning very complex, but it is also very personal and unique. Maybe any model for learning, if indeed models are even an appropriate thing to generate, must recognize the personal, almost religious element, that seems to be intertwined with the experiences of the child and other elements in their lives such as parents, siblings, personality, sense of self-esteem, hobbies, and general interests. Maybe the 'personal' outweighs everything else.

C. Benefits and Costs of Collaboration

At the conclusion of the study, Mrs. L talked about the potential benefits and costs that she realized. I also reflected on my own costs and benefits, and during the children's final individual interview, they briefly commented on their study experiences.

The majority of Mrs. L's experiences were positive. She spoke of the sense of personal, academic, and intellectual growth that she developed, and the enjoyment of having the opportunity to speak with another adult about her students and classroom. She commented:

> I have really enjoyed it. All these positive things happened. I have really enjoyed thinking about this and trying to make it work. That has been challenging.
>
> It's really been fun to have you peering in, and for me to have a chance in a quiet time to look at that and to see what was happening [in the classroom] on a minute to minute basis instead of the totality which is all I am used to dealing with.
>
> I'm also looking at my own teaching, I guess. It has really been interesting to see this as it was unfolding.
>
> Just having to come up with something to say about wondering, believing, and changing, for example. I think mainly just thinking about this [has been interesting].
>
> I have certainly been thinking about sound a lot, and classroom management, and organized activities for [the children].
>
> I've really liked reading the research stuff, too. I think I will probably apply some of the things that come out of [the research] too.

Mrs. L also encountered some costs of participation. Among these costs were time considerations, and her self-induced pressure to 'perform'.

> There were some costs, but I would say fatigue and pressure [were the main costs]. I stayed up later since we began getting some of the stuff done. I have felt the pressure. But, it's . . . a different kind of pressure. You are really motivated. . . . It is not a killing thing. It is an exciting kind of pressure. . . . self-imposed pressure. . . . This is a way a teacher would perceive [her]

> role here. If you are going to agree to do this, you would probably want to do a good job so that the study works out. Also, so you look all right.
>
> I think I stole a little more time for science from the other areas.
>
> [Also], I went from 9 til 10:15 until [the children] were just about huffing and puffing on their desks. . . . The children probably felt some limitations on this. Because they were pressed. I think the children felt [the science] coming on a little too quickly.
>
> The pity was there was just less time to do something I wanted to do better and more of, and, that was looking over your transcripts. More time to think over what I was doing here.
>
> One thing we could have done is talked about the possibility of finishing off in January, and the benefits of that to us in terms of getting that sleep, and feeling better about a little less pressure.

I also experience times when the study seemed to bear a high cost. Certainly, exhaustion arising from the pressure to complete interviews, transcribe tapes, and update the teacher took a toll on my physical and mental well-being. Nevertheless, my overwhelming experience of this study was a positive one. One of the greatest benefits for me lay in meeting a teacher who shared my interests and questions about elementary science education. I also learned that questions I had as an elementary teacher about maintaining an activity science program, and how children learn in that program, are shared by other teachers. Further, I was impressed with the quality of many people who teach children and their dedication to education.

Another benefit for me lay in sharing with the teacher the data, and the working copies of the study. It seemed more ethical to share the data with the teacher than to 'take away' the data, write a thesis, and then provide a copy of the thesis once it had met departmental approval. The method also avoided the situation in which the thesis might misrepresent the teacher's opinions, or appear to be more of an evaluation of the teacher instead of an exploration of the children's learning. Perhaps the benefits that I experienced, and Mrs. L's comments about her experience, suggest that excluding teachers from viewing and commenting on the data also excludes them from the growth and benefits which Mrs. L recognized, and may prevent the researcher from appreciating the position of a teacher whose classroom and teaching are being reported in a public document.

Finally, the costs and benefits of study participation to the five children who agreed to be involved in the interviews were examined. On several occasions, Mrs. L informally asked Christa, Victoria, Gordon, Bob, and Samantha about their experience of participation, and I also questioned the children about their reactions to the study during their final interviews. The only study cost which Christa identified was that she was sometimes called for interviews while ~~the teacher was~~ reading *The Hobbit* to the class, and this interrupted the story line for her. The rest of the children commented that they perceived no personal costs, and Samantha added that the interviews were easy because they simply reviewed what she had done in science class.

Clearly, perceptions of costs and benefits of collaboration by the teacher and me, and the children's response to their participation seem to suggest that this study was viewed in a positive way by all those involved. Mrs. L ended her final interview by saying that she would enjoy participating in another collaborative study. However, she qualified this remark by stating that the next time she would assume another attitude.

> What would I do differently? Probably just relax a bit more. I think I really wouldn't do anything differently. Whoever approaches me, I will take that approach on the merits I see there and make a decision based on what I think is in it for me and what I see is in it for the [other] person. . . . [Learning and studying about things] are the sorts of things I enjoy.

The experience of collaboration revealed some of the requirements, dilemmas, limitations, benefits, and costs of this methodology. Collaboration also exposed some opinions and comments that probably would have emerged had any qualitative methodology been used. However, perhaps only collaboration could have provided the teacher with the sense of sharing and co-leadership about which she spoke. Our frequent meetings, willingness to compromise, and recognition of each other's knowledge implied a community of learners working together towards some common understanding. Therefore, this thesis cannot be claimed or owned by one person. Instead, the collaboration made this study our study, and the channels of communication which were established may open the way for further studies, sharing, and mutual benefits.

In the next chapter, Mrs. L's presentation of the Sound unit is documented. The chapter begins with Mrs. L's proposed plans for the unit. These plans are followed by brief descriptions of the sixteen Sound lessons, and these descriptions are interspersed with comments by Mrs. L. These descriptions and comments provide additional insight into Mrs. L's experience of collaboration, and provide a background for the children's comments about constructing a personal understanding of the teacher's science which are portrayed in Chapter Seven.

Chapter Six

Teacher's Presentation of the Sound Unit

This chapter begins with Mrs. L's plans for the Sound unit, and then presents a chronological approach to the description of science lessons which comprised this unit. These lesson descriptions are interposed with comments Mrs. L made about her teaching, the lesson content, and the children. These comments provide some insight into Mrs. L's experience of teaching science, and together with the lesson descriptions, provide the background against which the children's comments can be interpreted.

A. Teacher's Initial Plans and Perceptions

1. Proposed Plans for the Unit on Sound

Although Addison-Wesley STEM Science textbooks are available in the classroom, Mrs. L has chosen to obtain most of her ideas and some of her worksheets about sound from a unit which has been developed by consultants within her school system. From this and other resources, she has assembled a framework that revolves around three main ideas: 1) How is sound made?, 2) How does sound travel?, and 3) How is sound received. This framework includes ideas about music, the physics of sound, and audiology. The teacher reasoned:

> All the things we do in science class, all the things we are talking about, I want them to realize that we are looking at one of these three aspects of sound. [I will] possibly use a little chart with those three concepts [on it] to keep going back to so [that] they know what we are talking about.

Despite the unit framework, Mrs. L realizes that the three questions overlap and that at some point she must present these three ideas as a whole.

a) How is Sound Made?

Mrs. L intends to begin with having the children listen to a number of sounds from their everyday life, and then having them start to think and wonder about the sounds. This will eventually lead into an exploration of the conditions necessary to make sound.

> I want to lead them through some thinking: you have to have a force, something has to move, [and] two things have to come together to make something move. We will make sounds and then we will analyze just what we did to make that sound and why there was a sound now and not a sound a second ago.

The teacher plans to have the children use a variety of concrete objects such as tuning forks, elastics, and sound sticks to demonstrate the science concepts, and to provide the children with a background against which new vocabulary such as the words 'pitch' and 'vibration' can be introduced.

> Some of them use that word [vibration], some of them don't. But, I want everyone to go through that unit and come out using that word. That would be one objective. To feel that they knew what vibration was and to be able to describe it.

Mrs. L will also try to integrate sound with other subject areas. This could take the form of having the children examine and perhaps invent a musical instrument, or researching a mini-report on some aspect of sound.

b) How Does Sound Travel?

Mrs. L has discovered that this aspect of her sound unit necessitates the introduction of the concept of matter. This is an abstract concept and she believes that the children find this to be difficult.

> I don't know if I have to, but, otherwise what are we talking about? I try to get this across by analogy and by comparison [by having the children act things out ~~and by~~ setting up simple models that the children can manipulate]. The difficulty is that [the children] then [sometimes confuse the analogy] with the thing. For example, [I use marbles to demonstrate molecular motion. The children may confuse characteristics of marbles and molecules]. When I'm talking about molecules I have to say, 'You can only believe me that this is the name we give to the smallest particles of something, and when you don't have something, you have nothing, and that's what we call a vacuum. That's very hard for me to even conceive.

The three phases of matter will be introduced and the children will use materials such as tuning forks, Slinkies, tin can telephones, and marbles to demonstrate aspects of how sound travels and of energy transfer. In addition to these classroom activities, Mrs. L plans to explore echoes and the speed of sound out on the school playground.

c) How is Sound Received?

This question involves the examination of the human ear and the range of human hearing.

> It is very early on [that] we have to talk about the ear and the fact it has a drum and it reacts to a physical push. And really, sound is just all in our heads. It isn't really there. It's really something jiggling inside of our heads.

The children will also explore machines that can record sound, the effect of sound vibrations, sound pollution, and a variety of practical uses for sound.

2. Teacher's Past Experiences of Teaching a Unit on Sound

Mrs. L admits that even she has difficulty understanding some concepts and ideas about sound. Some of the concepts she wonders about are the 'nothingness' of a vacuum, and whether sound that travels through a railway track is amplified by the track.

Mrs. L has found that she has to pay constant attention to the time restrictions of operating within a school timetable. These restrictions may serve to limit the amount of time children have for a task, the teacher's level of preparedness for the lesson, and the time available for speaking with each child about his or her ideas in science.

The teacher has noticed that it is difficult for children to pose and research their own questions about sound. Ideally, she would like to include more independent exploration in the unit, but she finds that many questions require advanced skills and science knowledge the children do not presently possess.

3. Teacher's Prediction of Students' Learning in Sound Unit

Mrs. L has discovered that children have their own belief systems and these stand to affect what they will believe and understand in the Sound unit. She wonders if believing something involves hearing about it and then finding it to be true for oneself.

The teacher also suspects that the use of analogies to teach abstract concepts stands to add to the children's misunderstandings. She wonders if these abstract concepts demand an almost "religious" belief from the children because the children are really being asked to believe something they can not necessarily see. Such terms as energy and matter seem to provide the children with particular difficulty.

Mrs. L believes that children need time to manipulate objects and personalize the learning. She feels that teachers sometimes rush onto another subject area just at the child's critical "learning/discovery point." Further, she has observed that children can experience sudden moments of understanding when they unexpectedly attach meaning to some formerly puzzling concept.

The teacher has found that the children's prior knowledge sometimes enables them immediately to answer some questions. This results in her having to deal with a classroom of children who possess a wide range of knowledge about the subject. Therefore, some children might find the unit to be redundant while others may be overwhelmed by the number of new and difficult ideas.

The teacher uses a number of general indicators to inform her about the level of learning the children have attained. Among these indicators are (a) the level of class discussion, (b) the children's ability to cope with the tasks, (c) the questions asked by the children, (d) interest and enthusiasm shown for activities, (e) the children's creativity in experimenting, (f) observations recorded in the children's notebooks, and (g) the children's ability to answer the teacher's questions. These general indicators are followed by a formal written quiz that is intended to summarize the unit's concepts. However, Mrs. L added that

> Since I am dealing with a whole class, this means that I don't really know, except in a general sense, what learning is taking place or how much any one individual really understands.
>
> Generally, teachers operate like this. We orchestrate

approved learning experiences trusting that something useful is taking place whether it's the intended content learning, socialization, or the gaining of experience with materials.

B. Introduction to the Sound Unit Lessons

The following sections describe the sixteen lessons presented in the Sound unit, and put forward the teacher's comments about these lessons [see Appendix H for Time Schedule]. Mrs. L speaks about the challenges of presenting activity science and sometimes of the frustration she feels about time restrictions and content matter. Following some lessons, there are no specific teacher comments. This is not to suggest that Mrs. L had no observations about the lesson, but rather that other responsibilities such as parent-teacher interviews, and the Christmas Concert were impinging on the time she needed for reflection.

The first lesson begins with an introduction to the Sound unit. In this lesson, Mrs. L has the children listen to a number of sounds, and then discuss how these sounds were made. She also outlines the unit framework and allows the children time to make their own sounds using a piece of paper.

C. Lesson Descriptions and Teacher Comments

1. Introduction to Sound Unit: 9:00 - 10:15 a.m., October, 27, 1987

[Samantha is absent from this class due to cello lessons; she is, however, still able to take part in the subsequent interview.]

The teacher begins by having several children present mystery sounds for the class to guess. They have brought objects from home such as a watch, hair dryer, toy helicopter, and musical instrument, and, while concealed from the class, they make sounds using these objects.

Then, Mrs. L demonstrates ten of her own mystery sounds and the children record their guesses on a worksheet. [Identifying Sounds]

> Next, the teacher tells the children to think about and record their ideas about how each of the sounds were made. This takes about seven minutes, and then these ideas are discussed by the entire class. During this discussion the children describe the actions used to make the sounds and the teacher guides them to generalize about how sound is made. Christa volunteers that you have to do some kind of movement with your hands to make sound and Bob states that you can use your hands to make a sound.
>
> The children are then given a piece of paper on which they write the word 'sound' and the teacher asks them to invent as many ways possible to make sound with the paper. The children try: blowing on the paper; crinkling it; twisting; biting; hopping on it; shaking it; making a megaphone and yelling through it; punching it; ripping it; and kicking. The class concludes with the children sharing their ideas about making sound with the paper and the teacher emphasizing that the children had to do something to the paper to make a sound.

Mrs. L felt that although the children enjoyed the activities, and invented an impressive number of ways to make sound with paper, they seemed puzzled about why she kept asking how the sounds were made. She wondered if the question seemed obvious to the children and whether they were really puzzled about her asking what appeared to be such a trivial question.

2. How is Sound Made?: 1:15 - 2:15 p.m., November 9, 1987

> [The teacher has been absent for the last 1½ weeks due to her illness. Christa misses this science lesson because of her involvement in the Academic Challenge program.]
>
> Mrs. L begins by having the children recall the October 27th lesson. Samantha volunteers that sound is caused by sound waves and Bob adds that paper can make sounds if you crumple, rip, or stomp on it. The teacher summarizes this by reminding the children that something has to be done before sound can be made.
>
> Next, the teacher takes a plastic cup and drops it on a table. She calls this a sound system and the children name the components of the system: cup, table, and hand. Victoria volunteers to put an elastic band around the teacher's cup and then she flicks the elastic band with her finger. The children identify the components of this new system: cup, elastic, and hand.
>
> Two worksheets [Sound Producer Systems; What Causes Sound?] are distributed and the children are asked to invent their own sound systems using: elastic bands, cards, wood

sticks, cups, pins, and boxes.

Approximately eight minutes later, six of the children are given the opportunity to share and demonstrate their sound system ideas. Then, for the next seven minutes, the remaining children exchange ideas and complete their worksheets.

During the last seven minutes of the class, several children read aloud from their worksheets while the teacher emphasizes that you have to do something to make a sound. Mrs. L calls this 'doing' a force and uses the examples of hitting, striking, and dropping to illustrate what she means by this term. Gordon identifies his hand as something that can cause a force and another child talks about the force of a stick hitting a drum.

The teacher found this lesson to be very tiring to teach because of her recent illness. We agreed that activity science required a high output of energy and Mrs. L questioned whether the children had really understood what she had meant by 'force'.

Mrs. L decides to include more science classes in the timetable in an attempt to make up for time lost to illness. Therefore, a lesson is scheduled for tomorrow which will expand the children's knowledge of movement, force, and sound.

3. Vibrations: 9:00 - 10:15 a.m., November 10, 1987

[Tuning forks, hockey pucks, and pans of water are on the table at the back of the classroom.]

The class begins with the children recalling the concepts introduced in the previous lesson. When Mrs. L asks for someone to define force, Victoria answers that it "is something trying to get something together."

Then, Mrs. L takes a tuning fork and strikes it against a hockey puck. She holds the tuning fork close to some of the children. Bob observes that he can see the tuning fork wiggle and other children talk about the movement and vibration.

Next, the children gather around the pans of water on the back table. Mrs. L strikes the tuning fork against the puck and lowers the prongs into the water. The children observe the splashes and are impressed with the demonstration. Gordon explains that vibrations make the lines on the surface of the water.

The children return to their desks and tuning forks and

> hockey pucks are distributed. For the next 13 minutes, the children strike their forks on their pucks and then touch the forks to various objects in the room.
>
> Finally, the children return to their desks and during a class discussion are able to tell the teacher that when they struck their tuning forks they observed wiggling and buzzing. They also use the term vibration and under the teacher's guidance they are able to recognize that this vibration is very fast. The children end the class by completing a worksheet. [Sound Section A: Student Sheet 4 - Feel Those Vibes]

Mrs. L commented that she is still uncomfortable with my presence in the classroom. She was very aware that the lessons were being recorded and observed and that usually she incorporated more humor into her lessons.

The following lesson builds upon the ideas of movement, force, and vibration, and Mrs. L uses these ideas to introduce and explain the phenomenon of amplification.

4. Making Sounds Louder: 9:06 - 10:15 a.m., November 12, 1987

> [Materials such as elastic bands, styrofoam cups, tuning forks, hockey pucks, and paper clips are sitting on a back table.]
>
> The teacher begins by reviewing the framework of the Sound unit. She emphasizes that a force in the form of some action is necessary to produce sound. The children recall and discuss various discoveries they have already made with their tuning forks, and Mrs. L tells them that the numbers written on the tuning forks refer to the number of times a tuning fork vibrates in one second. The teacher summarizes by writing the word vibration on the chalkboard and stating that vibration is needed to produce sound.
>
> Next, Mrs. L demonstrates playing a cello and the children observe that the strings of the instrument are vibrating.
>
> The teacher tells the children that today they will learn how to make sounds louder and the class provides some examples of things which are known to produce loud and soft sounds. Then, Mrs. L holds an elastic and the children suggest how she can make a loud twanging noise by plucking the elastic. They discover that a louder sound happens if the elastic is pulled further back before it is released. The teacher states that the louder sound is a result of putting more force into the pull.
>
> Mrs. L then takes a styrofoam cup and the children

> suggest how this cup can be used to make the elastic sound louder. The teacher attaches the elastic to the cup and a child plucks the elastic. The sound is louder. The children provide some tentative explanations about why the sound is louder and then materials from the back table are distributed. Mrs. L tells the children to try out some of their ideas and record their observations on the worksheet. [How Can You Make Sound Louder?]
>
> After several minutes of independent exploration, the children discuss the observations they recorded on their worksheets. About 2/3 of the class indicate that they made the elastic sound louder and the teacher tells them that the word amplify means to make sound louder. They then discuss the role of the cup in amplification and the children give a variety of answers. One child mentions that the elastic and the cup are both able to vibrate. The children conclude that the two ways they used to make sound louder were to add the styrofoam cup to the sound system and to pull the elastic band further back. The children further hypothesize about the role of the cup and the teacher guides them to the idea that the shape of the cup directs the sound and makes it louder.
>
> Next, Mrs. L takes a tuning fork and the children suggest various objects in the classroom she should touch with the tuning fork to test for amplification. Mrs. L tries their suggestions and Christa reasons that the cello amplified the sound of the tuning fork because it is hollow and 'there could have been echoing.' Another child says that the cello could be vibrating and the teacher adds that the entire surface of the cello is also vibrating.
>
> Finally, the children refer to a second worksheet. [Worksheet #3: Machines that Amplify Sound] They discuss such machines as radios, stereos, and microphones and then use the remaining 15 minutes of the class to finish the worksheets and spend free time in further manipulation of the tuning forks.

Mrs. L thought that the time spent reviewing concepts from the previous lesson was too lengthy, and she still felt nervous about having her lessons observed and recorded.

Her reading of the children's interview transcripts had indicated that the children experienced difficulty defining the word force. Therefore, today she purposely emphasized how the word was used in the context of the unit.

In the next science class, Mrs. L begins the first lesson which addresses the question: How does sound travel?. The concepts and ideas needed to explain this phenomenon are abstract and challenging, and Mrs. L anticipates the children will experience difficulty.

5. How Does Sound Travel?: 1:20 - 2:15 p.m., November 13, 1987

[A box of marbles sits on the back table and metal curtain rods are scattered about on the floor.]

The teacher begins the lesson by asking the children to listen for quiet sounds. The children name a few quiet sounds and the teacher observes that although she can see bushes and trees moving in the wind out in the schoolyard, she is unable to hear them. Mrs. L then tells the children that today they will be looking at how sound travels.

Mrs. L tells the children that the phenomenon of sound travelling is hard to show to people and that she will only be able to show what the travelling is like. Samantha immediately volunteers that sound waves are involved here but other children find this term to be puzzling.

Mrs. L tells the children that marbles and Slinkies will be used to show how sound travels. She begins by telling the children that there is a name given to small bits of matter that are so small they cannot be seen. The children make various guesses such as nucleus and microscopic and soon one child suggests the word molecules. About half of the children in the class indicate they have heard this word before. The children then wave their hands through the air and the teacher tells them that although they can't see anything in the air, there is still something there.

Five girls are selected to come to the front of the classroom and stand in a row. Mrs. L names these girls 'molecules' and has them stand at various distances from one another to simulate gases, liquids, and solids. Then, Mrs. L pushes the first girls in the line and this push is passed on to the end of the line. The teacher tries several more physical pushes and also has a student snap his fingers and send a 'push' through the girls. Mrs. L explains that this pushing is what is meant by a sound wave and that it is important to observe that the molecules are not moving but rather it is the push that is travelling though the molecules.

The teacher then takes a Slinky and the children move around a table to observe the action. One child holds an end of the Slinky and the teacher squeezes the coils and sends a vibration through the spring. The children make various observations and the teacher summarizes that the push or squeeze is passed along and that this is like a sound wave. She adds that there are many kinds of waves and a sound wave is a compression wave.

> Next, the children gather around the teacher who is now crouched by one of the metal curtain rods in the middle of which is a row of 12 marbles. The teacher rolls another marble toward the marble row. She tells the children to watch how the force goes through the marbles and they observe that one marble rolls off the other end of the marble row. Then, the teacher rolls various numbers of marbles toward the marble row and the children make predictions about how many marbles will roll away from the marble row. The teacher asks why the same number of marbles rolls off the end as are rolled towards the row and Christa replies that there is 'more force with three marbles than with one.' Another child reasons that 'it is like the same marbles come out again.'
>
> Next, Mrs. L comments that from a distance, she is unable to hear people snap their fingers. The children suggest various explanations and one child reasons that it is because the 'molecules can't push that far.' The teacher concludes that molecules lose a bit of energy each time they pass on a force and she demonstrates this by spreading the row of marbles so that they are about 1 cm apart and then once again rolling a marble towards the row. This time, no marbles roll away from the row and Mrs. L states 'that's why sound only goes so far.'
>
> Finally, the children spend the last 15 minutes of the class manipulating the curtain rods, marbles, and Slinkies.

Mrs. L was aware that she presented a large number of new and complex words. However, she had no expectation that the children would come away from the lesson being able to define the new vocabulary. Rather, her rationale for presenting this vocabulary was to show the children an appropriate situation in which the words could be used and to provide an initial introduction to words that would be needed in subsequent lessons. Mrs. L felt, however, that these same activities could be presented with the new vocabulary omitted.

The teacher used a number of analogies to present the idea of travelling sound waves. Her past experience with teaching this unit had taught her that children experienced difficulty with analogies and she felt uncomfortable discussing such abstract concepts with a grade four class. She doubted whether such young children were able to understand these concepts about sound and she believed that the children had probably focussed on the action of the Slinky and marbles and not necessarily on the analogy she was hoping to make.

Through reading the children's interview transcripts and participating in such an intense examination of her classroom, Mrs. L began to question the inclusion of this lesson's concepts in the elementary curriculum and wondered if she would even retain this lesson in her future unit plans. Also, her reading of the transcripts heightened her concern about the pace of the lessons. She felt that the children had inadequate time to make sense of the science and that the new vocabulary and concepts were simply 'coming too quickly.'

Despite her reservations about the abstract quality and pacing of the lesson, she felt that the children had enjoyed manipulating the materials, and had enjoyed the lack of written work.

In the next lesson, Mrs. L presents the process of human hearing and refers to such ideas as molecules, energy, matter, and force to describe how this process also involves sound travelling.

6. How Do We Hear?: 9:00 - 10:15 a.m., November 17, 1987

> [A plastic model of an ear sits on a table and on the blackboard are the following words: How Do We Hear?, outer ear, ear drum, three bones, hearing organ, cochlea, small hairs with nerve endings, nerves to brain, and brain understands sound messages.]
>
> The teacher begins by announcing that today's lesson will be on 'How Do We Hear?. She tells the children that to understand hearing, they must first understand how sound travels. Mrs. L briefly reviews how force is required to cause vibrations which then travel through matter in the form of sound waves.
>
> Next, Mrs. L selects a group of boys who move to the front of the room and form a lengthy line. The teacher

> pushes the first boy in the line and the push is passed through to the last boy who puts his hand in the model ear. Mrs. L tells the children that the push passes through matter, which they have previously referred to as being composed of molecules. Bob then volunteers that a push is being passed along through the line of boys. The teacher emphasizes that she has to use work to life her arm to push and that the harder the push, the more energy she has to use. One child volunteers that the 'pushing molecules' get the sound over to the other people in the line. Mrs. L repeats that there is energy in the push and that sound is a push.
>
> Then the children gather around the table upon which sits the model of the ear. The teacher identifies the various parts of the outer and inner ear, and how the sound pushes on the ear drum. She has several children hit a tambourine she is holding to show how sound hits the ear drum and causes vibration. Then she tells the children that there must be air on either side of the ear drum for it to vibrate and air is allowed into the inner ear through a tube found in the back of the throat. She continues that from the ear drum the vibrations pass to a set of small bones which make the sound louder and then the sound is passed to the cochlea. At this point, Mrs. L pauses, reviews these concepts, and adds that the cochlea passes the physical push of the sound waves to tiny hairs which are connected to nerves which pass a nervous message to the brain.
>
> Next, the children tell various stories of ear aches and infections and the teacher relates some first aid information about ears. Bob comments that he believes the explanation of hearing that the teacher gave but he is amazed that it all happens so fast.
>
> The children go back to their desks and the teacher hands out a worksheet [How the Ear Works: A Sound Receiver System]. The children work on this worksheet and also construct large ears from purple construction paper that they will wear to test for their amplifying effect.
>
> Ten minutes before the class ends the teacher asks the children to put on their purple ears and to listen as she bangs together some finger cymbals. She walks over to several groups of children and again bangs the cymbals.
>
> As the class draws to a close, the teacher calls for the children's attention and reviews how sound travels and how we hear. She emphasizes that you need something to pass the push, and that energy needs to be passed along.

The teacher noted that the children seemed confused about how sound travels and, specifically, about what was pushed along and the nature of the material through which the push travelled. Mrs. L thought that until she presents a lesson about sound travelling through solids and liquids, the children will probably be left with the impression that sound only travels through air.

Mrs. L also wondered if the children were able to conceive of hearing as being linked with a physical push. She commented:

> It really is hard to conceive that 'hearing' is a physical force causing a chemical-nervous experience in our brain. I can only think about that so long myself. [Bob] commented on how fast it all happens. . . . Again, that's where any demonstration such as the Slinky wave, marbles, kids in line, etc., still continues to puzzle, not to answer or clarify.

The teacher also noted that her explanation of tubes in ears seemed confusing to the children.

> I talked about the tube from the inside of the ear to the throat but standing there beside a partial model - which does not show mouth or tongue of course - I had a distinct impression from their faces and questions that they cannot visualize this anatomical set up.

Mrs. L concluded that the model of the ear helped to clarify her explanation but she felt she took too much time to present the information.

Mrs. L noticed that for many children, the hearing test with the purple ears did not seem clear. However, one positive aspect of the lesson was that she felt less aware of my presence and she reasoned that she must be getting used to being 'on display.'

The next lesson involves viewing a film which contains a number of demonstrations and concepts about sound. Some of the demonstrations repeat ideas from previous classes (e.g., Slinky demonstration), while others are intended to extend the children's knowledge, or act as precursors to future teacher demonstrations and class activities.

7. Film: Learning About Sound: 1:20 - 2:15 p.m., November 19, 1987

Mrs. L introduces the film by telling the children that the film will demonstrate how sound travels through different materials. She identifies solids as one form of matter and Christa volunteers that the two other forms of matter are gases and liquids.

Then, the class views the film which contains the following demonstrations and concepts: 1) a tuning fork causing vibrations and how vibrations travel; 2) a glass jar is filled with smoke for the purpose of letting us see that it contains air, a ringing bell is suspended in the jar and slowly the air is withdrawn by an electrical pump, soon the ringing cannot be heard; 3) Slinky demonstration; 4) defining frequency as the number of vibrations in a second; 5) amplitude; 6) a railway track in a desert area and two boys are standing beside the track about 300 m away from each other, first, one boy strikes the track with a hammer while the other listens with a stethoscope, then, one boy fires a gun while the other boy observes the delay of sound, the narrator concludes that sound travels through solid objects, and in steel sound travels 10 times faster than in air; 7) a diver ringing a bell under water; 8) hearing aids; 9) a dog whistle is blown which is inaudible to humans; 10) a cello is played and waves appear on an oscilloscope screen; 11) metal and plastic garbage cans are put on a driveway and the narrator comments on the noise pollution associated with various materials used to construct garbage cans; and 12) noise pollution is reduced by motorcycle mufflers.

After the film, the class reviews the contents of the film. Christa comments that light travels faster then sound and this was proven by the boys hammering on the railway track. The discussion continues for about 10 minutes longer and then the teacher asks the children to write down several sound questions about which they are now wondering. Several children immediately offer to the class their ideas for questions and Christa volunteers that one of her questions is 'How come there has to be a vibration or movement to make sound?.'

The children spend the remainder of the science class recording questions in their science binders. [see Appendix I]

Mrs. L thought that the children probably focussed more on what they saw in the film rather than the explanations they heard to support these observations. Although she believed that the vocabulary level was too high, the film did repeat some of the concepts already explored during previous science lessons and she commented that these seemed prominent in the film, and even aided her own understanding of sound.

The teacher also had several written comments which stemmed from reading both the children's transcripts, and my written records of previous science lessons. She wrote:

> I was struck by your observations that the time given for the children's activities in the science lessons you have seen is so short. Since that is clearly the part they value most (from their comments) it is an important issue for me to address. I have to ask myself - why do I think I must give such lengthy demonstrations and explanations? What would happen if I left a lot of that out and provided longer time with real materials?

My presence in the classroom also heightened the teacher's awareness of such issues as her classroom management and student discipline and how they might stand to affect children's learning in science.

> I have been wondering about the subtle (and unsubtle) effects of discipline, classroom management, climate, and the general state of the children on their learning of science. I would think these factors would in fact have important influences on the success climate for thinking more creatively in class. Also, [discipline and classroom management] affect the length of time [the children] can concentrate purposefully.

In the following lesson, Mrs. L expands upon the concepts of the speed of sound and the speed of light which were presented in the film. She also includes an echo activity to emphasize the speed of sound, and how sound travels

8. Echoes and the Speed of Sound: 1:15 - 2:15 p.m., November 20, 1987

[Prior to the commencement of the class, Mrs. L locates some rhythm sticks and two 70 cm lengths of wood two by four boards.]

> Mrs. L begins the lesson by telling the children that today's class will be about echoes. Christa offers that echoes can be found in the gym and other children suggest alternative locations. The children discuss what an echo is and some of the conditions they think are necessary for an echo to occur. The teacher then informs the class that they will be going outside to find some echoes. They will also be striking the two by fours together and listening for sounds much the same as the two boys near the railway track were doing in the film they viewed in yesterday's class.
>
> The children move outside onto the playground while Christa and Samantha check the interior of the gym for echoes.
>
> Gordon is chosen to take the two by fours and jog out to the far reaches of the playground. While Gordon is still running out into the field, the remaining children stand right next to the gym wall and a few of the children strike some rhythm sticks together. The children listen but cannot hear an echo. Just then, Christa and Samantha come running out of the school and report that they could not find any echoes inside the gym and perhaps it was because the gym was full of people.
>
> Then, the children count off ten paces from the gym wall and once again the rhythm sticks are struck together. This time the children hear an echo but report that the sound seems to be coming from several directions including from the houses and buildings which surround the schoolyard. They repeat this exercise three more times and then the teacher sends two boys, one of which is Bob, out into the field to Gordon to tell him to strike the two by fours together.
>
> The boys run across the field and deliver the message to Gordon who is just visible at the furthest end of the playground. The children observe Gordon hitting together the two by fours and about two seconds later they hear the sound of the hit. Both Gordon and Bob take turns hitting the two by fours.
>
> Next, the children return to the classroom and they review their playground activities during a teacher-directed discussion. Mrs. L uses a chalkboard diagram to illustrate echoes rebounding from the gym wall and Victoria comments that 'When they hit the blocks, two seconds later we could hear the noise.'
>
> The class concludes with a brief discussion about animals which use echoes and about how people use echoes in such devices as the Sonar used on fishing boats.

Mrs. L thought the children were very interested in the activity especially when they were able to observe Gordon striking the two by fours together.

We were all intrigued to see for ourselves the time lag between

> [the speed of light] and [the speed of sound] when the boys went to the far end of the field and clapped the boards together. It would be interesting to use binoculars and see if we could time an increased length of interval if a student went even further away - (maybe I would do this with students at a higher grade level).

The teacher also commented on how the students reacted to going outside for a science class.

> I have taken classes out to find echoes there for the last four years but this class wins the prize for giddiness. It is so important to be quiet and listen in this activity. They could scarcely have noticed much about echoes. This is an activity more successfully done by oneself or with a partner - I might try sending them out by themselves, or two or three at a time.

Mrs. L also wondered whether the children had understood the echo activity and the explanation behind what they observed. One of her Academic Challenge students did offer an explanation during the class discussion but she had her doubts about the comprehension level of the rest of the students.

> [One boy] could explain why we don't hear echoes close to the gym wall but could, [hear echoes] further out. I would like to know if he just thought of that or where he got the idea. I wonder if the class as a whole realized what we were doing out there.

Two days after this lesson, Mrs. L spent time writing about the different factors which she thought influenced the teaching and learning of science in elementary schools, and in her classroom. She began by listing positive factors such as (a) the inservice program offered by her school system, (b) the many science centers available in the area, (c) the interest shown by the parents of her students, and (d) her own science background. She did, however, recognize that in some classrooms science is taught sporadically, and she wrote about the challenges teachers face trying to present an activity science program.

First, although Mrs. L describes the science inservice program as being excellent and valuable, she admits that attendance at inservices does exact a toll.

> Teachers pay a price in fatigue and stress to make it to any inservice after school, but they keep returning to the science ones because they know they will be high quality, interesting, and practical.

Another challenge to an activity science program involves the financial support which must be supplied in order to purchase materials for the program. If this support is not forthcoming, supplies will be limited and this can add to the teacher's stress and responsibilities.

> [Supplies and resources] are probably the largest problem for teachers - finding some useful printed resources, getting together kits, and carrying stuff in and out of the class for the activities. It takes time to find and gather stuff - some of which can't be stored together so that it is ready for next time. Also, teachers share resources and equipment and may have to track items down in other classes or clean them.

A third factor which can influence an activity science program is the physical arrangement of the classroom.

> Teaching activity science is easier if the classroom has sinks, windows to grow plants by, low counters, shelving and storage. Flat-topped desks and separate chairs make it easier to do activities and alter desk arrangements for different purposes.

Timetabling and special school activities can also influence science in elementary schools.

> Activity science requires extra time and planning for getting materials out and doing the required clean-up afterwards. So often we have the recess or morning time that we have set aside in our minds for preparation time, taken up with discipline issues, phone calls, parents, or talking to other teachers or adminstration.
>
> We expect to have [timetabling] interruptions in

> elementary schools. This makes it hard to be always ready for science. I find I just go ahead anyway, in a less ready state.
>
> Science classes that I manage to be well organized for go so much better. This extra preparation time and clean-up time requires more energy and may be the major reason why some teachers don't keep up a consistent activity science program.
>
> I think schools have too busy programs these days. Time lost on all the extra events cuts into basic teaching time. I also think it keeps the children unnecessarily stirred up. Their environment is too exciting. It affects their concentration and requires increased effort on my part to keep them calm.
>
> Several of my students put in huge long days from before 8:00 a.m. to about 6:00 p.m. at the after school care program. It's a wonder they have the energy to think a straight thought about anything, including science class.

Library resources are needed for both the teacher and children to refer to when exploring science topics. Some ideas for science activities can be supplied by other staff members, however,

> teachers are really busy. They also are sometimes territorial about the units they teach or the special supplies used to present an interesting unit. There really has to be a lot of sharing, helping, and cooperating to help make science teaching successful across the grades in a school.

Mrs. L concluded that in recent years she observed greater pressure on teachers who must teach children, work within a school system, and yet be responsive to society's demands.

> Not only have budget cuts caused increased class sizes, reduced aid time, and resulted in less money for supplies, but at the very same time teachers are under increasing pressure to be responsible for more and more. The paperwork stuffed in our mailboxes is drowning us. The public have high expectations and quickly complain when they think standards are slipping. Teachers who love their job and try to cope with the extras are feeling exhausted, and frustrated.

In the next Sound lesson, Mrs. L again explores the question, 'How does sound travel?.' She has the children participate in activities involving tin can telephones, and a rubber hose, and these activities are intended to show that sound travels better through solids than air.

9. How Does Sound Travel?: 9:00 - 10:15 a.m., November 24, 1987

[Gordon is absent for this class.] A rubber garden hose trails across the floor of the classroom and out into the hallway. Tin can telephones and plastic funnels are on the back table.

Mrs. L has written several phrases on the chalkboard: What causes sound?, How is sound produced?, How does sound travel?, How do we hear sound?, How is sound received?, How do you make a tin can telephone work best?, What happens?, and What do you find out about sound from the tin can telephone?

The class begins with a student asking the teacher about the purpose of the rubber hose. Mrs. L turns the questions back to the children and they provide a variety of suggestions. One suggestion entails using the hose to talk to another person and about half of the children indicate that they have tried this on other occasions. The teacher guides the children to think about why a funnel could help them talk through a hose and then two boys are chosen to demonstrate the apparatus. The boys have difficulty hearing one another through the hose even though they yell quite loudly, and other children suggest that there might be kinks in the hose, that the hose might be too long, or that the sound is impaired because the hose bends around a corner.

Next, the children talk about the tin can telephone and the teacher refers to the phrases she has written on the blackboard.

Then the children split into groups, spread throughout the school's hallways, and try out the telephones and the hose. Mrs. L and I circulate through the halls and try to spend some time with each group.

After about half an hour, the children come back to the classroom and the teacher initiates a class discussion. Several children report that they experienced difficulty with hearing through both the hose and the telephone and other children offer solutions to their problems. The children conclude that their experience with the tin can telephone supports the idea that sound travels better through solids than gases, and the hose is an example of sound travelling through air.

The children suggest some further variables they would like to manipulate on the tin can telephone and they conclude

> the class with writing a paragraph about their experience with the tin can telephone. [see Appendix J]
>
> During recess, Samantha and Victoria take a tin can telephone and go out to the playground to try to discover the effect of string thickness on the transmission of sound.

Mrs. L noticed that the groups of children were in need of further assistance when they were working with their materials in the hallways. She wrote:

> The groups had several minutes head start to find out on their own about transmitting sounds along the string of the tin can telephone. When I went on my rounds, I found that few had figured out on their own that the string had to be pulled very tight. In fact, at least one set of girls [and another of boys] were sitting on the floor shouting into their cans while the string was looped in loose circles on the floor!
>
> I found that when I gave the groups a bit of coaching about how to hold the cans and string, and showed them a few ideas about plucking, scraping, or banging coat hangers on the string they had something to set off their own ideas. I seemed to arrive just in time to allay frustration. Once these technical problems were sorted out, their experimenting took more creative turns.
>
> The hose set-up seemed not to work as well as hoped for. Some thought they had it working well after some trials so perhaps it took a bit of experience or adjustment.

In this lesson, Mrs. L increased the time the children had for the actual manipulation of the objects, but she was still concerned that the children were only just beginning to explore.

> Again - it is time that is the big factor here. The class would find out more and think of more things to try with the cans and string if left indefinitely - to let the activity come to a natural close. However, as usual, we closed down the activity while several were just coming up with their best yet ideas. I am sure they must be feeling frustrated!

Mrs. L was also concerned about the noise level of the activities, especially since the children were working in the school's hallways. She recognized that other classrooms in the school might stand to be disturbed by the activity outside their classroom doors.

In the following lesson, Mrs. L explores how sound travels through solids, liquids, and gases. The children participate in some teacher-directed activities, and Mrs. L performs some related demonstrations.

10. How Does Sound Travel?: 9:00 - 10:15 a.m., November 26, 1987

[On the floor of the classroom are: two dry cells, and a bicycle pump attached to a stoppered jar within which is suspended a bell connected to the dry cells. On the chalkboard are the following statements: How does sound travel?, and Does sound travel better through other materials than air?.]

The class begins with the teacher telling the children to take out their science binders. Victoria commences to record written notes which she entitles: Interview Notes. Gordon arrives late and misses the first three minutes of the science class.

Then, the teacher tells the children that today's lesson will involve an investigation of how sound travels. She reminds them of the activities they did in the previous class and then she chooses a boy to assist her in a demonstration. Mrs. L taps on a desk as the boy listens with his head above, and then on, the desk. The boy compares the two sounds and declares that he can hear the sound louder when his ear is on the desk.

Next, Mrs. L has all the children independently try this demonstration and then she calls for their attention. The children are unanimous that the sound was louder when their ears were on the desk and the teacher records their conclusion on the chalkboard.

The children then divide into groups and carry out various investigations involving: tapping tables in the library, tapping the classroom air registers, and hitting and then listening to a tuning fork that is hanging by a string from their ear.

After about fifteen minutes the children return to their desks and copy the following question from the chalkboard: Does sound travel better through other materials than air?

Mrs. L initiates a discussion about the activities they have just completed and the results they obtained. The children agree that the sounds were louder through the table than the air and that the tuning fork sounded quite loud when it was suspended from their ears. The teacher summarizes that these two activities provided a comparison of hearing sounds through air and solids and then she poses a question

> about testing sounds through water. Christa suggests this could be tested by ringing a cowbell underwater at the swimming pool and then ringing the same bell above the water. Victoria speaks up to say that there are currents in the swimming pool which would prevent the clapper of the cowbell from being able to hit the bell. The teacher suggests that perhaps someone in the class could test this out at the swimming pool and report their results back to the class.
>
> Next, the teacher reminds the children of the film they viewed in which they saw two boys listening to sounds through the air and then comparing it to the sound through the railway track. She names the three states of matter and explains that 'The thing that is the difference between those things is what makes a difference to how sound travles.' Then, the children leave their desks and upon the teacher's direction, form two lines. In one line the children stand very close and are called a solid and the other line is spread apart and named a gas. The teacher pushes on the two rows of children and they observe that the solids are able to pass the push faster than the gas.
>
> The teacher then spreads out three of the gas 'molecules' and asks the rest of the children what lies between the molecules. The children make various guesses such as air and gas and one child suggests that there is nothing between the molecules. The children find this puzzling and one child explains that 'nothing is something that is not there.' The teacher calls this 'nothingness' a vacuum and uses space as an example of a place that has nothing in it.
>
> Next, the children move to the front of the classroom and gather around the teacher who has connected a bicycle hand pump to a stoppered jar within which is suspended a bell. The teacher begins to pump on the bicycle pump and states that she is going to take the air out of the jar to see if sound needs air through which to travel. Unfortunately, the equipment malfunctions and despite enthusiastic pumping, the teacher is unable to create a vacuum. Bob consoles the teacher and tells her that it worked on the film so they all know that it actually does work. The teacher asks the children what they would have seen if the equipment had worked and Christa answers that the clapper would have stopped. The teacher challenges this statement and another child suggests that the clapper would continue to move but they would be unable to hear it.
>
> Then, the children return to their desks and draw a diagram of the jar and bell demonstration. The class ends with a brief discussion about hearing sounds on the moon and in space.

The teacher was disappointed with the performance of the jar and bell. She had assembled it the night before the class, tried it out, and it worked. However, she felt that it could be important for the children to see a demonstration that did not work perfectly as it gave them a more realistic view of science.

The next lesson deals with the concept of pitch. In this class, Mrs. L has the children blow into pop bottles, and strike beakers which contain various amounts of water, and the children observe differences in pitch.

> 11. Introduction to Pitch: 1:00 - 2:15 p.m., November 27, 1987
>
> [On the table at the back of the classroom are wine and pop bottles filled with various amounts of water. Rhythm sticks are also on the table and there are other assorted beakers and pails of water situated around the classroom. The side bookshelf supports 12 large beakers containing differing amounts of water.]
>
> The teacher begins by displaying an empty pop bottle and a bottle within which is some water. She blows on each of the bottles in turn and then questions the children about the difference in the sounds. Samantha answers that the empty bottle has a lower pitch and the teacher informs the children that the word pitch has a number of definitions. They discuss other situations where they have used this word. Then, the teacher blows into a number of other bottles and the children make predictions about the pitch that might be associated with each bottle.
>
> Next, Mrs. L talks about using glass in the classroom and the safety rules by which the children are to abide.
>
> Then, bottles are distributed to the children and they begin blowing into the bottles and discussing among themselves. Some children strike the beakers with rhythm sticks.
>
> With fifteen minutes remaining, the teacher asks the children to return to their desks and they begin to discuss the activity. The children tell Mrs. L that different levels of water produce differences in pitch. Christa offers that pop bottles with more water give a higher sound and beakers with more water give a lower sound.
>
> The recess bell rings and Christa and Bob linger behind to try out more ideas with the beakers and the water.

Mrs. L was very aware of the safety concerns associated with having children work with glass.

> I suspect that I seemed over-firm. It is just that I have a vision of broken glass, a hurt child and then much answering to do. Who would ever have bottles and beakers in the class after that?
>
> It is a situation where I feel quite alone, never having seen another teacher deal with this, nor discussed with other teachers their way of laying out safety procedures. It's a matter of judgement. I want to set out firm expectations and guidelines yet not make them nervous about using the stuff. Nor do I want to appear over-anxious myself. They pick up on that.

The teacher also noticed that the children seemed to focus on what they actually did and saw during the activity while she wanted to encourage them to think about the reasons for their observations.

> You noticed me trying to converge questions on differences in pitch and what produced this. Meanwhile, the kids mostly wanted to report their other discoveries in exploring the beakers and bottles. They found out a lot about the qualities of the sounds and noticed that the same sound could be made by tapping different levels of water in same-sized beakers. The empty beakers have different pitches. It seems important to endorse their discovery agenda, even if it was not quite the one I had for them.

The next lesson is intended to expand upon the concept of pitch and demonstrate that additional objects can be used to produce variations in pitch. Mrs. L explains that pitch is related to vibration, and the children are given time to explore using their own materials.

12. Exploring the Concept of Pitch: 9:00 - 10:15 a.m., November 30, 1987

[On the table at the back of the classroom are the following materials: wood sticks, metal pans, bottles, beakers, elastic bands, combs, and cards.]

Mrs. L begins by reviewing the previous lesson involving the manipulation of bottles and beakers. Then, she announces that today's lesson will involve discovering more about pitch.

Next, Mrs. L demonstrates: 1) stretching elastics over a metal pan, putting a ruler underneath the elastics, and then plucking on the elastics; 2) stroking a card along the teeth of a comb; 3) placing a card on the spinning spokes of a bicycle tire; and 4) flicking a stick which she holds near the edge of a desk. Mrs. L tells the children to try these activities and encourages them to once again, try out the bottles and beakers. A worksheet is distributed and read [Pitch: High and Low Sounds], safety rules are reviewed, and the children spend the next half hour manipulating the materials.

After this time has passed, Mrs. L asks the children to return to their desks and she explains how to complete the worksheet.

Then, Bob demonstrates how to produce a change in pitch with the card and the comb. Another boy demonstrates blowing into the bottles and when Mrs. L asks the children about what could be vibrating and causing this sound, Victoria volunteers that both the bottle and the water vibrate. The teacher responds by using the example of a church organ to explain that it is the column of air within the bottle which is vibrating.

Finally, the lesson concludes with short demonstrations and discussions about the remaining objects which the children used during the class.

During the morning of the next day, Mrs. L shows a film which contains examples of animals who can hear through air, water, or solids. In the afternoon, Mrs. L introduces the mini-reports the children will write on some selected science topic. This introduction is followed by a teacher demonstration of pitch, and the children's performances of songs using materials from previous science classes.

13. Film: Animals Hear In Many Ways & Lesson: Exploring Pitch: 9:00 - 9:30 a.m. & 1:15 - 2:15 p.m., December 1, 1987

Film Description

I was not in attendance for this 12 minute film entitled: Animals Hear in Many Ways. However, the teacher took notes in my absence. The film contained three main ideas: 1) animals that hear sound through air, 2) those which hear through water, and 3) animals that hear through solids. These three ideas were illustrated by references to various animals such as elephants, birds, insects, bats, fish, and snails. The film concluded with a review of how sound is produced, how it travels, and how sound is received. The teacher concluded the class with a short review of the film.

Lesson Description

Mrs. L begins by introducing the mini-reports on sound which each child will be required to write and present to the class.

Then, Mrs. L reviews the discoveries the children made about pitch in the last two science lessons.

Next, the children watch as Mrs. L sets up a wash tub, broom handle, and string. A child volunteers to demonstrate this apparatus and discovers that when the string is tighter it produces a higher sound. Christa suggests that plucking the string in different places can also cause a variation in pitch but when she tries this out, she is unable to hear a change in pitch. Another student suggests putting one hand on the string while plucking it with the other hand. Mrs. L tries this suggestion and the children hear different pitches. The teacher tells the class that the 'thing' that was changed in each case (e.g., length of string) is called a variable.

Finally, the children divide into groups and each group confers together and plans to perform a song in which the science materials from previous classes are used to produce differences in pitch. After seven minutes of planning, each group performs a song for the class. Three out of five groups perform jingles from television advertisements.

In the next lesson, the children view a film about noises common to everyday life, and they participate in identifying sounds associated with aspects of their own lives. Mrs. L concludes with classroom examples of materials which are capable of absorbing sound.

14. Film: Noises & Lesson: Evaluating Sound: 1:10 - 2:15 p.m., December 7, 1987

[Christa misses the majority of this lesson due to her involvement in Academic Challenge. However, prior to the class, Mrs. L briefed her on the lesson's concepts and Christa also took the time to complete her worksheets.]

The teacher begins by telling the children that this will be their last lesson on Sound and that today they will discuss how sound affects them.

The children volunteer examples of sounds that they enjoy or dislike. Then, Mrs. L defines noise pollution and tells the children that this term will appear in today's film.

Worksheets [Sound Pollution and Evaluating Sound] are distributed and the children each generate an inventory of ten sounds that they associate with either breakfast or recess. After ten minutes, some children read and discuss their inventories with the rest of the class.

Next, the teacher introduces the 10 minute film [Noises] which the children then view. The film contains the following concepts and questions: noises are part of everyday life; some noises disturb or bother us; noises at home; neighborhood noises; noises at work, school, and a factory; going to sleep at night; how does noise affect people?; and what can be done about noise pollution?. After the film, the teacher reviews the main ideas and the children provide illustrative examples.

Then, the children study their Sound Pollution worksheet. Mrs. L tells them that the ceiling tiles in the classroom have little holes in which sound can bounce around and lose some energy. Two children also identify the walls and rug as materials capable of absorbing classroom sounds. Samantha adds that curtains can also absorb sound.

Finally, the teacher concludes the lesson by displaying a book containing pictures of baffles and sound barriers.

The next lesson is the last class prior to the Sound unit quiz. In this lesson, the children review the concepts they were exposed to during the unit, and observe additional examples of sound absorption and amplification.

15. Insulation & Unit Review: 9:00 - 10:00 a.m., December 8, 1987

Mrs. L begins by reviewing how some materials are capable of absorbing sound and how others provide insulation against unwanted noise. Gordon offers examples such as ceiling tiles, highway sound barriers, textured walls, and rugs and Samantha suggests that couches are also able to absorb sound. The teacher summarizes that all of these objects have surfaces which are capable of absorbing sound.

Then, Mrs. L takes a ringing alarm clock and wraps it in a sleeping bag. The children observe they are unable to hear the clock in the sleeping bag and the teacher tells them this is another example of a material that can absorb sound.

Next, the teacher displays a packing bag taken from a bat of fiberglass insulation and the class reads from the bag that fiberglass has sound control properties.

Then, the teacher plays a small hand-cranked hurdy gurdy and asks the children how she can make the sound louder.

Samantha suggests the teacher play the hurdy gurdy while it is against a hard flat surface. The teacher tries this and the children are impressed by the louder sound. Other children suggest alternative surfaces in the room on which to try the hurdy gurdy and the teacher follows their directions. Then Mrs. L tells the children that the sound is louder because the wall or desk is vibrating to the tune of the hurdy gurdy.

With 30 minutes remaining in the class, the children divide into groups and work on categorizing some sound review cards under three large heading cards on which are printed the sound unit framework: 1) How sound is made, 2) How sound travels, and 3) How sound is received. The children discuss the cards and attempt to place them under the appropriate heading. [see summary in Appendix K]

The class concludes with the teacher telling the children that they will have a Sound unit quiz on December 10.

16. Sound Unit Quiz: 9:00 - 9:50 a.m., December 10, 1987

Mrs. L begins by giving directions about writing the quiz and using time efficiently. Victoria asks if a question about how fast sound travels is on the quiz. Other children want to know how many questions are on the quiz and what they should write down if they don't know the answer.

The quiz is distributed and during the science period, about ½ of the children get up and manipulate materials such as the tuning forks and puck, and the beakers and water. Victoria, Bob, and Gordon all ask the teacher questions during the quiz. Samantha joins them to use the available science materials.

At the end of the class, about 3/4 of the children indicate that they thought the quiz was easy. Another five children raise their hands to show that using the science materials helped them with the quiz. [see Appendix L]

The quiz written today was the second rendition of a quiz that was initially prepared by the teacher. Both the teacher and I agreed that the first rendition of the quiz was quite difficult. Consequently, yesterday the children spent time suggesting appropriate questions for the quiz, and reviewing some of the concepts taken during the Sound unit. After that class, Mrs. L used some of their questions to write a second rendition of the quiz and this was the quiz which the children wrote today.

The teacher felt that Victoria sought a lot of help from her during the quiz. Mrs. L also predicted that the children would have problems with the bat question [Question #12] and maybe this would be due to the problems they had understanding the word 'navigate'. Twenty five children wrote this quiz and the class average was 89% with a range of 70% - 100%. Christa and Samantha received a mark of 100% on the quiz as did three other children in the classroom. Bob attained 97%, Gordon, 85%, and Victoria, 73%, which was the second lowest mark in the classroom.

D. Summary Discussion of the Teacher's Presentation

This teacher-directed Sound unit was conceptualized within a framework of three questions, and was presented through the use of teacher lectures, class discussions, teacher demonstrations, films, models, and teacher-directed activities. The children also compiled mini-reports on a chosen topic in sound, and were given credit for the report if they carried out independent research on their mini-report topic primarily by reading library materials. Evaluation of the unit concepts took the form of worksheets and a summary quiz, and this evaluation revealed that Victoria in particular experienced some difficulty with the concepts included in the Sound unit.

Mrs. L's comments revealed that she was aware the children needed more time to complete and reflect on the teacher-directed activities, that the children found some science vocabulary to be difficult, that she was unsure about the appropriateness of some of the science concepts, and that ideally she would want to include more opportunities for independent student exploration.

Additionally, Mrs. L recognized that her actions, available time, and activities were all influenced by factors associated with the system in which she worked. This seems consistent with Apple and King's (1976) comment that "teachers are not free to define the classroom situation in any way they chose" (p. 117). Instead, Mrs. L's enthusiasm for an activity science program had to be balanced against time restrictions, availability of science materials, financial considerations, special school activities, the physical arrangement of the classroom, and her level of energy. Mrs. L also drew attention to society's demands for increased services even during times of financial restraint. Apple and King (1976) reason that:

> The teacher's activities must be understood not merely in terms of the patterns of social interaction that dominate classrooms, but in terms of the wider patterning of social and economic relationships in the social structure of which he or she and the school itself are a part. (p. 124)

Perhaps our final reaction should be amazement that Mrs. L was able to maintain the energy level not only to plan and execute this varied and interesting approach to Sound, but she was also able to assume the additional responsibilities of collaborative research. These lesson descriptions and teacher comments, however, only reveal a small part of the children's experience of participating in the Sound unit as seen from Mrs. L's perspective, and from mine. Alternative framework researchers claim that children have their own ideas about the teacher's science, and that children's experience of the science lesson may not approximate what the teacher intended. This is not due to any perceived teacher incompetencies, but it is more an outcome of the prior knowledge the children bring to the lesson, their willingness to construct a personal understanding of the teacher's science, and the links the children generate between the teacher's science and what they already know. In the following chapter, the children's comments about their experience of the Sound unit are presented, and what emerges from these comments is a description of the children's struggle for a personal understanding of the teacher's science.

Chapter Seven

Children's Experience of the Teacher's Science

This chapter begins with brief descriptions of the five children who participated in the study, and presents their initial ideas about sound, learning, and understanding. The children's comments about learning and understanding reveal that they perceive a difference between these two terms, and that understanding involves the ability to go beyond recalling and repeating the teacher's science to a state where the children provide explanations which they construct themselves and which they judge to be personally satisfying.

The remainder of the chapter examines what is involved in the children's struggle for a personal understanding of the teacher's science, and emphasizes that this struggle is not characterized by linear, progressive stages. Instead, the children display many reversals of direction, make surprising observations, and construct webs of ideas which are intelligent and personal. However, the complicated, evolving ideas which the children possess are difficult to portray and study without providing some organizing framework. Therefore, the children's comments about their struggle for personal understanding are, in part, set against the framework of the Generative Learning Model (Wittrock, 1977, 1981, 1985). This learning model, and the vocabulary Wittrock (1977) uses to describe human thinking, however, seem to portray a view of constructing meaning which is more mechanical than what emerged from the children's comments. Therefore, Schutz's (1971) phenomenological description of a stranger who approaches and tries to understand and adopt a new culture is interwoven with the Generative Learning Model to provide more insight into the children's very human experience of the science.

A. Children's Initial Ideas and Perceptions

1. Children's Initial Ideas About Sound

The children met with me for their first individual interviews on October 26. During this interview, the children recounted the ideas they already had about sound and also provided an opportunity for me to gain a brief insight into their personalities.

As the study progressed and the children's unique views of sound were uncovered, the teacher and I wondered if the personality, philosophy, and homelife of each child explained much of what we observed. In an effort to provide us with more information about the children, the teacher recorded her own impressions of the children's personalities, and I further asked each child to describe his or her own personality and also to comment on his or her philosophy of school and science. Some of these comments appear in the following introduction to the children's initial ideas, and others emerge throughout the remainder of this and the subsequent chapter.

a) Christa

Christa describes herself as being a girl who is almost always good, who assumes responsibility for her schoolwork, and performs well with little adult supervision. She claims to enjoy school and feels personally motivated to constantly improve upon her report card marks. She is particularly enjoying this year in school because she is now the oldest member of her family enrolled in elementary school. With this status has come additional responsibility to ensure that her younger brother reaches the school safely.

Christa views school science as being both easy and fun. Although she did not identify components of science which she disliked, she said she did prefer performing experiments and trying out things. Christa thinks that the information the teacher presents during science class was originally discovered by scientists, and then was recorded by writers of science books. The science that Christa does in the classroom is different from that done by scientists because

> C: . . . scientists want to figure out one thing and they go ahead straight to it. We just sort of learn what the scientists have learned but we do different stuff. We do stuff we can do, like, we don't do big humungous machines.

Christa is currently participating in the Academic Challenge program at the school and enjoys the puzzles and independent work which are associated with that program.

During her initial interview, Christa spoke of the events from everyday life that were her sources of ideas about sound. Conversations with her parents, television viewing, and observations of people with hearing aids provided some of Christa's ideas. The specific ideas she had about sound are outlined in Table 1 where they are organized according to the teacher's unit framework.

b) Victoria

Victoria recently moved here from Ontario and was

TABLE 1

Christa's Initial Ideas About Sound

1. How is sound made?

   - things have to move to make a sound
   - sounds can differ from each other: higher and lower, louder and softer

2. How does sound travel?

   - [unable to offer an explanation about how sound travels]
   - sound travelling through solids is dependent on the thickness of the solid
   - it is possible to hear through liquids, but not very well
   - we can hear better in air than water
   - she can hear echoes in streets and in her father's empty darkroom; a big, empty space is needed for the best echo; an echo can also be heard in a big, furnished room

3. How is sound received?

   - [unable to offer an explanation about how ears work]
   - some people have difficulty hearing and use hearing aids which operate something like a microphone
   - some animals can hear better than others (e.g., dogs, monkeys), but you can't tell by just looking at the animal

4. New Vocabulary

   - Vibration: when you yell through a rolled up paper you can feel it wiggle back and forth; vibrations can be strong enough to break windows; loud noises make vibrations

   - Energy: there are different kinds of energy; batteries give off energy; people running marathons have lots of energy

   - Matter: as used in the statement, 'Matter of fact' enrolled in Greenwood School at the end of September. She is the oldest of four children in her family, and describes herself as being intelligent and possessing a sense of humor. Meeting other students and maintaining friendships with them is important to her and she misses the many friends she had in Ontario.

Victoria kept a particularly neat science notebook and consistently tried to do what she considered to be a good job.

> V: . . . if I do well, I'm a good student. If you just scribble all the time, I don't think you are that great. You can fail, too.

This sense of responsibility extended to the interviews where she would sometimes arrive with brief handwritten notes about the science class just completed. She would then use these notes to assist in answering the interview questions.

Victoria thought the majority of science classes were interesting. She preferred classes in which she was able to participate, and especially liked doing experiments and learning new facts. Victoria thinks that the information that the teacher presents in science class originated from scientists, and she describes science in the following way:

> V: Science is learning. Like, experiments, and new things and things that have just been invented a while ago which wasn't invented a long time ago.

Victoria has viewed movies which have featured scientists and she thinks that scientists

> V: . . . have moustaches and long beards, and they wear sort of a canvas suit. They go around and get fossils and they test.

When I asked Victoria what it was like to be a student in her science class she answered

> V: If I have something that sort of looks boring, I sit there and watch it and it is like watching the TV channel that gives you the shows. Science is just something that I enjoy and you never know when you get older I might not like it or I might like it more.

Her least favorite part of science is the summary quiz. Victoria finds test situations to be intimidating and she commented that sometimes she gets so nervous she is not able to think of the test answers. She would like to see the teacher include more games, experiments, and competitions in the science program.

When I interviewed Victoria about her initial ideas about sound she referred to many sources of information: television cartoons and science shows, a former unit on sound she completed in Grade Three, magazines, and observations from her everyday life. Her initial ideas are outlined in Table 2.

c) Gordon

Gordon believes his older sister and his friends would describe him as being funny and weird. He feels he is a good person and likes helping people and playing with his friends. It is important to him to complete his homework and he always puts forth an effort in school.

Gordon has a rural background and moved to the city prior to the beginning of the school year. He misses his farm, but has developed a friendship with another Grade Four students who lives within his housing complex. Many of his explanations about concepts in sound drew upon the experiences he had living on a farm and participating in sports with his father.

It was important to Gordon that he do well in school and he described science as being 'fun and neat.' During science classes,

TABLE 2

Victoria's Initial Ideas About Sound

1. How is sound made?

- people have voice boxes located in the middle of their chests which are used to make sound
- some things have to move to make a sound e.g., bells
- some things make a sound but do not move e.g., timers, fire bells
- sounds can be made louder or softer e.g., playing the piano harder; your mind telling your voice box to say things louder or softer
- high notes are louder
- some sounds such as sheep voices stay the same

2. How does sound travel?

- sound travels by vibrations; she has seen vibrations on cartoons and they are imaginary lines that float through the air, go in every direction, and make noises; vibrations can make a bell noise but do not come out of a radio because the speaker is covered
- it is possible to hear through solids e.g., she hears through her bedroom wall
- you can hear underwater at the swimming pool; vibrations might be involved
- can hear better in air than water because water currents prevent you from being able to strike sticks together with sufficient force
- echoes repeat what you say and are found in mountains and big empty rooms

3. How is sound received?

- people hear with eardrums inside their ears
- some people have hearing aids and tubes to help them hear; if you can't hear, you can't talk; sound gives you balance
- in general, you can hear things because they're close
- some animals with big ears, e.g., tigers and rabbits, can hear better than others

4. New Vocabulary

- Vibration: imaginary lines that make noise and go in every direction
- Energy: a good sleep gives you energy; energy is used in machines; energy is like electricity; running and exercising gives you energy
- Matter: used in the phrase, 'What's the matter?'

he prefers to do experiments and to find out new things. Gordon thinks that the ideas presented during science classes were discovered by scientists who have spent time doing experiments, but he added that the science done by a scientist is different from the science he does in school.

Gordon identified several sources of information for his initial ideas about sound: family members, radio, exposure to a unit on sound in Grade Three, and observations from everyday life. His ideas are summarized in Table 3.

d) Bob

Bob feels he is a curious person and he likes to understand why things happen the way they do. He believes he is a good person and if he does well in school then that will lead to a better and more successful life as an adult. Bob's parents emigrated to Canada and are very appreciative of the school's educational experiences. They have emphasized to Bob that it is possible to succeed in this new country through hard work and determination.

Bob displayed a consistently positive attitude towards Grade Four and especially appreciated the role Mrs. L had in his learning. Bob felt that her presentation of the lesson was key to attaining high test scores and he listened attentively during all science lessons.

Bob thinks that the information the teacher presents in class originated from scientists who have published information in books which are accessible to the teacher. He believes that the science done by scientists is more difficult than what he does

TABLE 3

Gordon's Initial Ideas About Sound

1. How is sound made?

   - things have to move to make a sound; even objects like a stereo that doesn't appear to move, still has knobs that move
   - sounds can differ: higher and lower; louder and softer
   - factors involved include the material of which the object is made; the amount of force applied to the object

2. How does sound travel?

   - we can hear things because they are close e.g., recess bell
   - we cannot hear through solids because they block the sound
   - we can hear through liquids e.g., underwater sounds at the swimming pool
   - we can hear better in air than water
   - an echo is your voice bouncing back to you; echoes are found in mountains, tunnels, trains, and big places where there are surrounding walls

3. How is sound received?

   - people hear with their ears; some people have difficulty hearing so you must speak up or they must use hearing things in their ears
   - some animals hear better than others e.g., eagles have a hearing scent

4. New Vocabulary

   - Vibration: happens when you hit a stick against a tree and your hands shake

   - Energy: you need energy for running; get energy from sugar

   - Matter: world / everything is made out of matter; matter is made of small bits of something; some things have no matter in school because scientists use a more advanced vocabulary and perform more experiments.

Bob's initial ideas about sound appear in Table 4 and some of the sources of his ideas are conversations with his brother and parents, observations from everyday life, and his own ability to understand and reason.

e) Samantha

Samantha enjoys science lessons and is particularly pleased when she is able to do hands-on activities. She is less enthusiastic about reading activities and she observed that writing made her hand tired. Samantha describes herself as being a person who usually puts in an average effort at school, but she still spoke of the importance of attaining good marks.

> S: Sometimes I'm grumpy. Sometimes in the morning when it is too early for me, I fell lazy and I stay in bed a little longer, I try to, but my mom comes and pulls me out. At school, not bad. Nothing much at school.

Samantha's family is from Sri Lanka and she is the only child of her professional working parents. Since she is enrolled in the after-school program, Samantha spends a long day at school and is further involved in taking piano and cello lessons.

Samantha attends school 'to learn' and adds that other children attend school

> S: To learn more that they don't already know. They learn their ABCs but they need to learn more than that to get a job and grow, enough to get food and all that.

Samantha thinks that science concepts were discovered by scientists and that this information is presented by the teacher during science class. However, she believes the science that

TABLE 4

Bob's Initial Ideas About Sound

1. How is sound made?

   - some things have to move to make a sound e.g., musical instruments
   - some things can make a sound but do not move e.g., photocopiers and air conditioning systems
   - sounds can be made louder and softer, higher and lower; variables involved are the energy used to strike the instruments and pressing different notes on the piano
   - wind is also capable of making a sound

2. How does sound travel?

   - ears attract sound to them and the sound goes into your ear; it is like how magnets attract each other; he wonders if sound moves through air, goes into your ears, and you hear it
   - when planes take off they leave the sound behind them; some planes go faster than sound
   - you can hear through solids depending on how thick they are
   - sometimes you can hear through liquids
   - echoes are a bit higher than the original voice and can be heard in large pipes and mountains
   - some people can make loud sounds and break glass

3. How is sound received?

   - people hear with their ears and their brain also helps
   - some people have difficulty hearing and they must use hearing machines
   - some animals like dogs can hear better than other animals

4. New Vocabulary

   - Vibration: [he has heard his brother use this word]

   - Energy: gives more strength and better hearing

   - Matter: [unsure what this word means]

scientists do is slightly different from that performed in science class

> S: . . . because scientists mostly work fixing things up. We read and do experiments. They do experiments, too, that's one thing that is alike with is and the scientists. But, they don't read as much as us, I think, because they know a lot about it. They went to school before us.

Samantha identified many sources of information for her ideas about sound: conversations with family members, music lessons, television cartoons, books, observations from everyday life, and previous exposure to sound in other school grades. A summary of her ideas are outlined in Table 5.

2. Children's Initial Ideas About Learning and Understanding

Alternative framework researchers have said that upon conclusion of a science unit, children may possess a variety of ideas about the teacher's science (Biddulph, 1982b, 1982c; Driver, & Erickson, 1983; Driver, Guesne, Tiberghien, 1985; Osborne, & Wittrock, 1983; Tasker, 1980). However, despite possessing a range of ideas about the teacher's science, children may use their recollections of the teacher's presentation of the science to pass exams and fulfill other formal school requirements. This may imply that although children may be willing to repeat the teacher's science during formal evaluations, some children may not feel confident about or even understand the explanations they offer during test situations. Children's willingness to repeat ideas presented by the teacher may also imply that there is a science which some children learn for school, and there is a personal science which to them may seem more understandable, useful, or meaningful.

TABLE 5

Samantha's Initial Ideas About Sound

1. How is sound made?

   - some things have to move to make sound e.g., opening a door
   - [unsure whether movement is always necessary for sound]
   - sounds can be louder and softer, higher and lower: factors involved include turning up the volume on the TV; hitting something harder; playing different notes on musical instruments

2. How does sound travel?

   - sound travels via sound waves which travel to your ear and then you hear; sound waves have to move quickly, although sometimes they are slow; if the sound waves are loud, they can travel through walls; sound waves are invisible and cannot be felt; their existence is proven by the fact that they can be heard
   - sound can travel through solids and liquids
   - we can hear better in air than water
   - echoes might involve bouncing sound off a wall and then you can hear yourself again; echoes are found in mountains, washrooms, and places where there are surrounding walls

3. How is sound received?

   - people hear with their ears and sound waves travel into the ear and then to the brain
   - some people have difficulty hearing
   - some animals can hear better than others but it doesn't necessarily depend on ear size

4. New Vocabulary

   - Vibration: lines that move back and forth; the wind can make vibrations

   - Energy: there is energy from appliance cords plugged into walls; batteries have energy

   - Matter: as used in the phrase, 'It doesn't matter"

There are studies which illustrate the variety of ideas and explanations children possess about topics in science, and present the comments children offer about what they thought they learned from the teacher's presentation of the science. In these studies, definitions have been generated and categories have been created which portray the children's reaction to the teacher's science. Strike and Posner (1985) distinguish between understanding science and acquiring verbal behavior about science, and say that "to understand an idea is to know what it means" (p. 222). This understanding can then be used to employ the idea in an "intellectually productive way" (p. 212) which is in contrast to simply acquiring a "piece of verbal behavior which one emits to a stimulus" (p. 212). Novak (1985) refers to Ausubel's discussion of rote learning and meaningful learning and comments

> [Ausubel] defines meaningful learning as non-arbitrary, non-verbatim, substantive incorporation of new knowledge into a person's cognitive structure, whereas rote learning is described as arbitrary, verbatim, non-substantive incorporation of new knowledge into cognitive structure. (p. 190)

Brumby (1981) also recognizes that children have different reactions to the teacher's science and she makes a distinction between concepts which children "'know' without thinking about" (p. 24), and concepts which are "meaningfully learned" (p. 21).

Clearly, there has been a recognition of and differentiation between scientific information which seems superficial, rote, and cursory, and that which appears to be more meaningfully grasped, understood, and eventually applied by the children. I wondered if the children in this study might also display these reactions to the teacher's science, and whether they would be willing to admit to possessing different degrees of understanding. If the children did admit to a range of reactions to the teacher's science, it seemed that this could provide a starting point for the examination of issues such as how the children interacted with the teacher's science, factors which might influence meaningful understanding, and how the children constructed meaningful understanding. I also wondered about what vocabulary should be included in my interview questions. Certainly, asking children to identify ideas they had learned by rote or were 'intellectually productive' is inappropriate. Consequently, I selected the terms *learn* and *understand* because these terms would be familiar to the children, and because these terms had been used successfully in another study concerned with exploring and defining children's reactions to teacher's science (Rennie, 1981). Therefore, prior to the commencement of the *Sound* unit, I asked the children about *learning* and *understanding* and whether they perceived any difference or similarities between the two terms. All of the children argued that there was a difference between these two terms, and proceeded to provide examples from their science units to support their claims.

Christa said she had *learned* about how magnetic north and true north were two different places, but she was unable to *understand* how they were different. Gordon felt he had *learned* that magnets could repel each other but he still did not *understand* why they would repel. Bob stated that he had *learned* about compasses, but remained confused and did not *understand* some aspects of their application. Victoria reasoned that when she is first exposed to a concept, she learns it but she may not understand. However, through studying the information over a period of time she maintained that she may be able to understand. Samantha thought ahead to the Sound unit and suggested that although she had already learned the words sound waves, she did not understand how sound waves were produced.

These comments establish that for these children, learning may have involved only memorization or the ability to repeat terminology or observations, while understanding meant an ability to provide an explanation that felt personally satisfying. Clearly, the children were able to perceive a range in their reaction to the teacher's science and implicitly recognize the difference between learn and understand, and this suggests that during the progress of a science unit, there are concepts about which they feel different degrees of confidence.

The children's comments about learning and understanding are similar to the categories and discussion that has been presented by Rennie (1981). Rennie (1981) studied secondary school students' perceptions of learning and understanding and said that the students described learning as being a "'mechanical process' or 'memory exercise' which involves knowing the formulas and definitions which enable [the children] to pass exams" (p. 46). Further, these students perceived understanding to mean "knowledge of the concepts and theory behind the laws and definitions" (p. 46). Rennie (1981) then drew parallels between the students' definitions, and White's (1979) discussion of achievement, proficiency, and mastery.

With the establishment of the existence of a range of reactions to the teacher's science and the children's ability to identify and define that range of reaction, perhaps what we can now ask is how the teacher's science progresses from being something which is merely learned by the children to being an idea which is personally understood by the children. Also, what motivates children to do beyond 'memorizing and repeating' the science even though this alone might be rewarded by the school system? Further, how does science become more personally satisfying and understood, and what is involved in the construction of personally satisfying understandings?

Perhaps some initial insight into what might be involved in the evolution of learning into understanding can be gained from Barnes' (1976) comments about rote learning, reflexive learning, and understanding. Barnes (1976) argues that "it is [the] grasp of principles, of underlying structures, which makes the difference between rote learning and understanding" (p. 114). He adds that

> Learning can be a passive acceptance of the beliefs and practices of the people about us. . . . Reflexive learning seems to occur when learner[s], acting upon purposes which are significant in [their] life worlds, [are] faced with disjunction between [their] implicit beliefs and those of the persons [they are] interacting with. This disjunction compels [them], if [they are] to continue [their] proposed action, to bring to sharp awareness parts of [their] world which were upon the periphery of [their] consciousness, and to construct for [themselves] understandings which did not previously exist. (p. 106)

In this quotation, Barnes (1976) suggests that learning involves a stance of passivity and acceptance of the words of others. Reflexive learning involves judging the significance and worthiness of pursuing alternative ideas, the possible recognition of dilemma or conflict, and the decision to actively struggle towards a fuller understanding.

I wondered if the children in this study would be more inclined to be content with learning science, or whether they would venture into the struggle for understanding that Barnes (1976) calls reflexive learning. Could the children identify classroom factors which influenced their learning and understanding or would this prove to be too difficult? Were there stages involved in the evolution of understanding or would the children's struggle prove too entangled to analyze? Finally, what might their comments as they participated in the Sound unit say about the struggle for understanding, and the children's potential adoption of new schemes of understanding?

B. Children's Learning and Understanding During the Sound Unit

After each lesson in the Sound unit, I asked the children what they had learned and what they had understood. For the most part, the children's comments about what they had learned during the Sound unit paralleled the comments about learning they offered prior to the commencement of the unit, and included: (a) the actions needed to carry out the tasks, (b) factors involved in the tasks, (c) what they had observed during the tasks, (d) the teacher's description of the task, and (e) the definitions for new vocabulary.

However, some of the answers the children gave to my question regarding what they had understood about the lesson were varied, occasionally vague, and sometimes surprising. For example, sometimes the children would claim that they understood 'everything' about the science lessons despite later admitting that there were aspects of the lesson about which they were puzzled.

> V: I understand everything the teacher said.
>
> V: I don't really get what [molecules] means.

In other instances, the children would claim that they understood a concept, and yet their explanations of the concept seemed to conflict with what the teacher intended. This seemed to support Nussbaum and Novick's (1981) contention that children possess the ability for 'understanding differently' rather than simply 'not understanding'; they emphasized that the children's understandings were personal understandings. However, in general, the children described understanding as the possession of sufficient knowledge to explain the reasons behind the observations they made.

Although my questions regarding learning and understanding had, in part, been intended to reveal science concepts about which the children felt unsure, it seemed that the children at times struggled to sort their thoughts into these categories. Christa indicated that sometimes it was difficult to decide what she had learned because some of her thoughts seemed to fall into both categories.

> C: Well, if you learn [an idea], you sometimes understand [the idea] too. Like, you understand how it worked, and you understand why it worked.

Also, it seemed that the children struggled with my questions about 'learn' and 'understand' because, whether 'correct' or not, most of their ideas were in the process of becoming a personal understanding.

This process which preceded a personal understanding of the teacher's science was one in which the children struggled with information which could appear both familiar and foreign. At times it seemed easy for the children to make links between the teacher's science and what they already knew, and other times the teacher's science appeared startling, counterintuitive, and unbelievable. During the struggle, the children had to possess motivation necessary to risk leaving the security of ideas which they already had, and sometimes this motivation arose from a number of external and internal sources. The children also had to evaluate and weigh the teacher's science, and construct personal meanings which they then had to judge against their prior ideas. Finally, not only did the children have to construct their personal meanings of the teacher's science, they also had to accept and believe these meanings.

This struggle for personal understanding seemed to be influenced by the nature of the teacher's science, the children's prior knowledge, and the personality and intellectual abilities of the children. Several of the science concepts were abstract and could only be presented by analogy, and some children found these concepts to be particularly difficult. Also, the children's prior knowledge, and the experiential and linguistic foundation of this knowledge, was continually referred to by the children, and this affected the nature of the children's understanding of the teacher's science. The children's personalities and intellectual abilities seemed to be an important and yet elusive factor in the children's struggle. On some occasions, Mrs. L and

I could predict which child would be more likely to appeal to adult authority, or would challenge the teacher's science, or would modify or change his or her current ideas about the science, or would express doubt or wonder about the science. On other occasions, we were surprised by how the children approached and reacted to the teacher's science. Also, some children seemed to experience much difficulty and frustration with the science, while others seemed to possess such clear vision and impressive logic that it appeared they expended little effort in coming to a personal understanding of the content and implications of the teacher's science.

Wittrock (1977, 1981, 1985) has formulated a *Generative Learning Model* which Osborne and Wittrock (1983, 1985) have used to interpret children's struggle for understanding in science. This model was discussed in detail in Chapter Two; briefly,

> The generative learning model is centrally concerned with the influence of existing ideas on what sensory input is *selected* and given *attention*, the links that are *generated* between stimuli and aspects of memory store, the *construction* of meaning from sensory input and information retrieved from long-term memory, and finally the *evaluation* and possible *subsumption* of constructed meanings. (p. 64)

This model provides a valuable guide to the interpretation and discussion of the children's comments in this study. However, although Wittrock (1977, 1981, 1985) has been careful to include additional comments about motivation, student responsibility, attention, and about how the construction of personal understanding is not a single-path or single-loop process, the children's comments in this study suggested that there are other important elements to children's thinking during school science.

During the study, the children's risk-taking, frustration, hesitation, persistence, and enthusiasm revealed a very human experience of science understanding. It seems possible to understand this experience, at least in part, by using the metaphor of a stranger who approaches a new culture and attempts to understand and adopt that culture as his or her own. Schutz (1971) describes the stranger as lacking the history of the approached group and therefore the stranger must start to interpret the new culture in terms of his or her "thinking as usual" (p. 97). The stranger discovers, however, that the new culture is in contrast to his or her home surroundings and this is frequently the "first shock to the stranger's confidence in the validity of his [or her] habitual 'thinking as usual'" (p. 99). When the stranger experiences this culture shock and recognizes the limits of his or her 'thinking as usual', this gives rise to the realization that "the normal way of life is always far less guaranteed than it seems" (p. 104); by approaching the new culture, the stranger stands to lose his or her status, rules of guidance, and even his or her history. Schutz (1971) concludes that

> The stranger discerns, frequently with a grievous clear-sightedness, the rising of a crisis which may menace the whole foundation of the 'relatively natural conception of the world', while all those symptons pass unnoticed by the members of the [new culture]. (p. 104)

Schutz (1971) maintains that the stranger then begins a gradual process of social assimilation into the new culture.

> If we encounter in our experience something previously unknown which therefore stands out of the ordinary order of our knowledge, we begin a process of inquiry. We first define the new fact; we try to catch its meaning; we then transform step by step our general scheme of interpretation

> of the world in such a way that the strange fact and its meaning become compatible and consistent with all the other facts of our experience and their meanings. If we succeed in this endeavor, then that which formerly was a strange fact and a puzzling problem to our mind is transformed into an additional element of our warranted knowledge. We have enlarged and adjusted our stock of experiences. (p. 105)

At first, Schutz's (1971) description of a stranger approaching and attempting to understand and adopt a new culture may simply appear to be another way of stating Piaget's ideas about assimilation and accommodation, and really not to contribute to an understanding of the children's human experience of science. What is important about Schutz's (1971) description, however, are the recollections and empathetic understanding it evokes. At some point, everyone has experienced being a stranger. We all know what it is like to enter a new classroom, begin a new job, or attend a social gathering where only the host is familiar. We know that much more is involved in these situations than making observations, trying to fit new information into what we already know, and translating the new situation into familiar terms. We know that the stranger's experience also involves an emotional, personal reaction that could range from feeling anxious, insecure, or threatened, to feeling neutral, curious, or challenged. In this respect, approaching a new culture, or a new idea, is an experience which challenges our intellect and is intertwined with our emotions.

Therefore, Schutz's (1971) description of the stranger's experience of approaching a new culture, and in particular, the vocabulary he uses to portray the process of social assimilation, will provide a framework for examining the children's comments about their struggle for personal understanding. During this struggle, the children risk leaving the familiar to create a variety of mini-theories, or tentative responses to the teacher's science, arises the beginning of a new sense of security (Smith, 1987).

C. Children's Struggle for Personal Understanding

The children's struggle for personal understanding arose out of the children's willingness to approach the teacher's science, to observe the teacher's science, to construct meanings of the teacher's science, and to judge whether they would accept or believe the meanings they constructed of the teacher's science. Underlying these active mental manipulations were such issues as the children's loyalty to the teacher, the extent of their belief in the authority of adults, their willingness to take risks, and their confidence in their own intellectual abilities. By examining the words of the children as they participated in the Sound unit, and by using frameworks provided by Osborne and Wittrock (1983, 1985), and Schutz (1971), more insight can be gained into how the children constructed a personal understanding of the teacher's science.

1. Defining the New Fact

Schutz's (1971) description of the experience of a stranger offers that the stranger begins a process of social assimilation into the new culture by trying to define the new facts. Osborne and Wittrock (1983) say that the pathway to constructing meaning begins with selective attention to sensory input, and they further describe this attention as involving a voluntary controlled effort. Regardless of what labels are attached to this phenomenon, it is important to realize that this is not an isolated, separate phenomenon, but rather it is inevitable tied to the generation of links between prior knowledge and sensory information, and the interpretation of that information. However, in order to add some clarity and organization into this discussion about the children's experiences in Sound, some arbitrary boundaries need to be drawn. Therefore, for the purposes of this discussion, this section entitled Defining the New Fact will present the children's experiences of trying to ascertain the purpose of the lesson or task, and their experiences of making observations of tasks and demonstrations.

a) Lesson and Task Purpose

During this study, there were instances when the children were unanimous about their conception of the purpose of the lesson, and other occasions when the children held a variety of opinions about both the lesson and its purpose. What seems evident from the children's comments is that a variety of factors influenced their ability to answer my question regarding the purpose of the teacher's science. These factors are summarized in Table 6.

i) Agreeing About the Purpose of the Lesson or Task

In six of the sixteen lessons in the Sound unit, the children were able to agree about the overall purpose of the lesson. An examination of their ideas about the purpose of the lesson reveals that the children displayed different degrees of insight. During two of the lessons, the children could only agree that the lesson was about sound. After another lesson, they focussed on the new materials they manipulated and agreed that the purpose was to make sound with tuning forks. In two other lessons

TABLE 6

Factors Influencing the Children's Perceptions of the Purpose of the Teacher's Science

A. Agreeing About the Purpose of the Lesson or Task

1. Factors related to the teacher's presentation of the science
    - a) Novelty of objects used in the lesson
      e.g., agree that the lesson is about tuning forks
    - b) Repetition of a concept
      e.g., agree the lesson is about sound
    - c) Perception of a meaningful question
      e.g., How do people hear?

B. Disagreeing About the Purpose of the Lesson or Task

1. Factors related to the teacher's presentation of the science
    - a) Level of difficulty or abstractness of science concept
      e.g., use of an analogy for how sound travels
    - b) Level of participation in a demonstration
      e.g., direct participation versus observation
    - c) Format of the lesson
      e.g., inclusion of several related but discrete activities within one lesson
2. Factors associated with the children
    - a) Prior ideas about the science concepts
      e.g., ideas about energy and molecules
    - b) Familiarity with objects used in the lesson
      e.g., marbles are used to play games
    - c) Inclination to wonder about the purpose of the lesson

they identified the concept of pitch as being the purpose of the lesson and on November 17th they all recalled the teacher's question 'How do people hear?' and maintained that this question described the purpose of the lesson. These ideas about making sound with tuning forks, about pitch, and about the process of hearing approximated the teacher's intended purpose of the lesson.

The children's comments may imply that factors such as the novelty of the science materials, or the repetition of a concept, or perhaps even the children's perception of a meaningful question, may influence children to agree upon the purpose of the lesson. However, at this point it does not seem clear or certain what potentially stood to give rise to a consensus among the children, and perhaps an examination of instances when the children disagreed might provide additional insight.

ii) Disagreeing About the Purpose of the Lesson or Task

On November 13th, the children all observed the teacher demonstrate rolling marbles along a curtain rod. The teacher's purpose for this activity was to provide an analogy for how sound travels. The children, however, offered a variety of opinions about the purpose of the task, and this made explicit that the nature and substance of the connections they made between the teacher's science and what they already knew was a factor in their perception of the purpose of the task. Christa reasoned that the task was intended to show that force goes through marbles. Bob talked about how this activity showed that molecules can push, and Samantha thought the task demonstrated that vibrations could pass through a row of marbles. The comments these three children made may imply that they realized the demonstration was an analogy for how sound travels, and that they were able to associate the demonstration with previous tasks involving force, molecules, and vibrations.

Victoria, however, thought the teacher performed this demonstration to show that marbles could make a rattling sound on curtain rods. Victoria added that these curtain rods resembled the balance beams in gym class, and she knew that balancing was associated with hearing.

> V: All I heard was rattling [marbles] going down [the curtain rod]. I heard that [balancing has something to do with hearing] . . . if you're balancing on a beam, your ears help you.

Although Victoria was aware that the demonstration had something to do with sound, her comment shows that she did not realize the demonstration was an analogy for how sound travels. It is difficult to discover why Victoria did not recognize the analogy, but she may have simply found the idea of an analogy to be difficult to comprehend, or found the concept to be too abstract or puzzling to understand, or perhaps she did not hear the teacher's announcement about the purpose for the demonstration, and did not feel that another purpose even existed.

Gordon wondered why Mrs. L would play marbles in the middle of a science class. At home, marbles were objects with which to play games.

> G: [My dad and I] had a humungous piece of string and we moved all the furniture into the hallway and we made a circle and we played marbles with each other.

Not only does Gordon's comment suggest the influence of his homelife, but it may also call into question the practice of using common, familiar, objects in the science program which are intended to encourage children to see the science that exists in everyday objects and activities. Clearly, Gordon's comment suggests that the use of everyday objects can also result in confusion and difficulty.

The level of participation in a task could also influence the children's perceptions of the task's purpose. During the November 20th lesson, the children explored echoes and the speed of sound out on the school's playground. Both Bob and Gordon too an active part in hitting together some 'two by four' wooden planks as part of a demonstration to compare the speed of sound with the speed of light. Their participation, however, seemed to influence their perception of the task's purpose. Bob and Gordon thought the demonstration was about echoes because as they stood in the playground and hit the two by fours together, they could hear echoes bouncing off the surrounding houses. They were also aware that the teacher had announced that this demonstration was intended to explore the speed of sound. Therefore, Bob and Gordon adapted the teacher's purpose to their own and reasoned that the sound from the two by fours had to travel to the houses and then back to their ears before they could hear the echo.

The format of the lesson could also influence the children's perceptions of the task's purpose. In the November 20th lesson involving the playground activities, the teacher chose to include an activity about echoes, and an activity about the speed of sound. Although these two activities are related, perhaps their inclusion in the same lesson could have influenced Bob and Gordon to assume that both activities were about echoes, and perhaps this might also explain their perception that the speed of sound demonstration was, in part, about echoes.

On November 9th, Gordon commented that he was unsure about the purpose of the lesson, and his uncertainty about this aspect of the teacher's science occurred frequently throughout the remainder of the study. At times I wondered if he was simply having difficulty with the format of the interview question or was not familiar with the vocabulary I used. However, in his final interview he clarified that his reticence to voice his opinion about the purpose of the lesson was, in part due to the fact that he was not in the habit of questioning why he did school lessons, and he also found it difficult to know what the teacher had in her mind. This might imply that although Gordon was actively trying to understand the lesson, and was genuinely interested in the science, he still felt a sense of separation from the lessons perhaps because of the source of the science, or his practice of not questioning the status quo.

These examples of times when the children held a variety of ideas about the purpose of the lessons and tasks demonstrate some of the discrepancies which appeared. Clearly, in some instances "the pupil-perceived purpose for the task is not the teacher-perceived purpose for the task" (Tasker, 1980, p. 5). However, this should not imply that the teacher did not clearly communicate the purpose of the task or lesson, nor should it imply that the children avoided trying to discern the overall meaning of the teacher's science. Instead, the children's attempts to capture the meaning of the teacher's science meant that they had to relate the science to ideas they already possessed, and this will always result in opinions about the science which can be as diverse as the children themselves. Therefore, perhaps what is most surprising is the tendency to operate on the assumption that children have opinions about the science which are congruent with the teacher's, because if children are to come to some personal understanding of the science, they should display disparities while they attempt to personalize the science.

b) Making Observations

In addition to the existence of discrepancies between the teacher's purpose and the children's perceived purpose, were instances when the children agreed about their observations of the teacher's science, and many times when the children disagreed, or showed slight variations, in their observations. The factors which influenced the children's observations are summarized in Table 7.

i) Agreeing About Their Observations

On November 19th, the children viewed a film entitled Learning About Sound. In this film, a dog whistle was blown which, although inaudible to humans, resulted in a dog running towards a person with the whistle. After the film, the children agreed that they were unable to hear the dog whistle, and then they all proceeded to recount homelife experiences with dog whistles. Perhaps their recognition of a familiar situation, and their similar, personal, prior experiences with dog whistles

TABLE 7

Factors Influencing the Children's Observations of the Teacher's Science

A. Agreeing About Their Observations

1. Factors related to the teacher's presentation of the science
    - a) Teacher's use of familiar objects
      e.g., dog whistles
    - b) Demonstration includes obvious, dramatic features
      e.g., sound is louder when a cup is added to the sound system; marbles roll away from row
2. Factors associated with the children
    - a) Prior experiences similar to teacher's science
      e.g., homelife situations involving dog whistles

B. Disagreeing About Their Observations

1. Factors related to the teacher's presentation of the science
    - a) Demonstration requires the children to make fine observations e.g., number of marbles which roll away from the row
    - b) Level of difficulty of the activity
      e.g., constructing purple ears
    - c) Scheduling of the activity
      e.g., prior to recess
2. Factors associated with the children
    - a) Prior experiences with science phenomenon
      e.g., sound is slightly louder or much louder
    - b) Anticipation of the activity outcome
      e.g., purple ears must amplify sound
    - c) Strategic inattention
      e.g., not paying attention to the demonstration
3. Factors associated with the research design
    - a) Interview situation involves risk for the child

in part influenced their consensus. However, there seemed to be many more times when the children displayed some variation among their observations. Perhaps by examining moments of disparity, it will be more clear what seems to be influencing the children's observations.

ii) Disagreeing About Their Observations

On several occasions, the children agreed with each other about the immediately obvious, grosser features of the demonstration or activity, and yet disagreed about the finer aspects of the demonstration or activity. After the November 12th lesson, the children agreed that by adding a cup to the sound system, the sound of the elastic was louder. However, Victoria claimed the sound was slightly louder while Christa maintained that the sound was much louder. Perhaps the girls' answers are simply a matter of semantics, but perhaps their answers do imply that when they compared the sound to their prior knowledge of amplification, they each arrived at a personal observation of the teacher's science.

During the November 13th lesson, the children watched the teacher's demonstration with the marbles and curtain rods. Although it seemed clear to me that the same number of marbles rolled away from the marble row as were rolled towards the row, the children did not necessarily make this observation, and I wondered if my past experience with this demonstration and my anticipation of the results influenced me.

After Victoria watched this demonstration, she maintained that when the teacher rolled two marbles towards the marble row, only one marble rolled away. Samantha claimed that two marbles made three roll away. Although the girls' comments establish that they had noted the obvious movement of the marbles, they still arrived at their own individual conclusions. This was in spite of the teacher specifically asking the children in the class, 'Why did the same number of marbles roll off the end of the row as were rolled towards the row?', and one child remarking that 'it is like the same marbles come out again'. Perhaps such issues as anticipation, prior knowledge, strategic inattention, or the skills required to make an accurate observation of the finer points of the teacher's science, could have played a roll in influencing the girls' comments.

On November 17th, the children participated in the purple ear activity which was intended to provide the children with another experience of amplification. After the activity, Samantha claimed that she could hear sounds better without wearing the purple ears. Christa maintained that the purple ears made no effect on the sound. Gordon observed that when he wore his purple ears, sounds appeared much louder. In this lesson, it seemed that the children were unable to agree on even the gross features of the activity. Perhaps this was in part due to the nature of the task itself. Some children experienced difficulty constructing their purple ears and others found it challenging to keep the purple ears attached to their own ears. Also, this activity took place near the end of the lesson and the children were obviously anticipating the impending recess. Perhaps if factors involved in the construction of the purple ears had been controlled, and the room had been perfectly quiet, the children would have displayed greater consensus among their observations. Also, maybe Gordon's comment about the efficacy of the purple ears implies that he had anticipated the amplifying affect of the purple ears because a previous lesson had introduced the word amplify, and this word had once again been included in the purple ear lesson. These instances of discrepancies among the children's observations suggest the role that such factors as anticipation, prior knowledge, former science lessons, attention, the nature of the task, and the skills of the children might play in the children's observations of the teacher's science.

In addition to these times of agreement and disagreement were a small number of instances when the children had difficulty recalling their observations of the lesson.

iii) Strategic Inattention

Sometimes the children found it difficult to remember the content of the lesson, or recalled details which were not presented during the lesson, or were unable to recall the observations they made while manipulating materials. One reason for these difficulties was offered by Victoria when she admitted that she could not provide an explanation for the sound-absorbing quality of acoustic tile because she was not 'paying attention.' Shapiro (1987) also encountered a student in her study who admitted to inattention, and Shapiro (1987) commented that it seemed the child's attention was dependent on his interest and curiosity in the teacher's science. McClelland (1984) has argued that students' "strategic inattention" might be a more parsimonious and probable explanation for why children have mistaken the purpose of a science activity than an explanation "in terms of different conceptions held by teacher and pupils" (p. 5). Certainly, if children are not attending to the lesson this obviously stands to affect their perception of the lesson's purpose, and their degree of personal understanding. What is probably most prominent in this study, however, is the observation that strategic inattention seemed only rarely to occur in this particular situation.

Perhaps another explanation which might account for some children's difficulties with recalling lesson details involves the interview itself. Implicit pressures may be brought to bear on a child during an interview situation (Claxton, 1986; Driver, & Erickson, 1983; Driver, Guesne, & Tiberghien, 1985; McClelland, 1984; Osborne, & Gilbert, 1980). Weber (1986) describes the interview situation as holding the potential for trust and commitment, and as holding the potential for abuse or betrayal. Both the child and the interviewer run the risk of revealing themselves, and if children are aware of this risk, and are overly concerned with pleasing others, or feel they must always offer some answer, it is only reasonable to assume that the content of their answers might stand to be affected. Therefore, perhaps children's inability to recall information about the science lesson, or their willingness to offer details which were not presented, might in part be explained by the technique used to uncover their ideas.

c) Summary Discussion

These examples of consensus and disagreement reveal that each child was unique and brought different past experiences and knowledge to the learning situation. This background knowledge could result in a variety of outcomes including moments when children made similar observations, made different observations, perceived the teacher's intent, or formulated their own purpose for the task or lesson. This knowledge could affect the children's anticipation of the lesson, and possibly could affect their ability to cope with the lesson. Additionally, such factors as attention to the teacher's science, the format of the lesson, the level of participation in the lesson, the objects included in the lesson, and the difficulty of the teacher's science could also influence the children's perception of the science.

Driver, Guesne, and Tiberghien (1985) have made similar observations about the diverse interpretations children may display in science and it seems that Tasker's (1980) statement about the difficulties this may pose for teachers is correct. Tasker (1980) wrote that "what makes science teaching based on pupil involvement with investigative tasks so difficult is that any one factor is often sufficient to prevent pupils having the expected experiences" (p. 11).

Perhaps any discussion which establishes that children do not necessarily make the observations and perceive the purposes intended by the teacher naturally leads to concerns about how classroom teachers should react to this information. Osborne (1985) suggests that discrepancies should be "identified and discussed [before] much of the value of the lesson can be lost" (p. 17). Perhaps, however, there are additional educational and ethical issues involved in a concern about discrepancies.

If discrepancies among the children's comments are simply an outward indication of the children's struggle for personal understanding, then perhaps we should ask if it is wise to interfere in this process, and if teachers even possess the power to influence much of this aspect of personal understanding. Also, perhaps we should ask if it is even ethical to demand that children modify their ideas about the teacher's science. Conversely, it would seem only reasonable to expect that teachers concerned with impending exams and evaluations would desire that students should perceive the intended purpose of a lesson, and make observations which the teacher planned they would make. Certainly, this issue presents a dilemma for educators and researchers which may prove difficult to resolve.

The children's previous comments about the purpose of the lessons and the variety of observations they made about the lessons among other factors, point to the importance of the nature of the links children make between their own knowledge and the teacher's science. At times, these links allowed the children to perceive the teacher's intent, and at other times, these links seemed to influence the children to form a variety of ideas about the teacher's science. In the following section, I present the kinds of links the children made during the study, and the challenges they faced attempting to make connections between the ideas contained within those lessons.

2. Linking With the Familiar

The children's comments about the observations they made and the purposes they attached to various activities and lessons, revealed that such issues as anticipation, prior knowledge about sound, former science lessons, and homelife experiences could affect their ability to cope with the lesson. The reason these issues could affect the children's ideas is that the children related the teacher's science to what they already knew, and this act of relating or linking could result in the children making similar observations, different observations, perceiving the teacher's intent, or formulating their own purpose for the task or lesson.

Schutz (1971) recognizes this phenomenon of 'linking with the familiar' when he states that

> the approaching stranger has to 'translate' [the new culture's] terms into terms of the cultural pattern of his [or her] home group, provided that, within the latter, interpretive equivalents exist at all. If they exist, the translated terms may be understood and remembered; they can be recognized by recurrence; they are at hand but not in hand. (p. 99)

Osborne and Wittrock (1983) have noted that the construction of personal understanding involves a 'linking with the familiar', and they offer that "tentative links [are] made and tentative meanings constructed prior to the final construction of meaning" (p. 494). Osborne and Wittrock (1985) also have reviewed research pertaining to children's connections and conclude that "it would appear that pupils have no difficulty generating links from sensory input to existing ideas" (p. 69).

Certainly, the children in this study made links and constructed explanations which evolved and changed as the science unit progressed. However, the terminology that Osborne and Wittrock (1983, 1985) have selected to describe children making links may be misleading. A phrase such as 'generating links from sensory input to existing ideas' suggests that children rigidly employed some mechanical approach to the science. Instead, the children in this study at times showed that there was a creative, imaginative element to their approach to the teacher's science, and that perhaps this creativity was a precursor to the links they made.

a) Creative Element

Driver (1981) has warned that we would be mistaken if we concluded that children arrive at their alternative frameworks simply through the process of induction. She adds that "there is also a creative and imaginative element involved on the part of each child in constructing [the] meanings he [or she] imposes on events" (Driver, 1981, p. 95).

On November 9th, the children watched a film which contained examples of objects capable of making sounds. One of these objects was a cello and while it was played, wavy lines appeared on the screen of an oscilloscope. Most of the children simply explained that the wavy lines were in some way connected to the sound made by the cello. Victoria, however, expounded upon this demonstration and in doing so she exposed the creativity and whimsy which preceded her final explanation.

> V: Well, you know [what] me and my friend were doing? We were trying to see what [the wavy lines] were. We thought one was a mountain and one was a monster. Okay. I think they hook something onto [the oscilloscope]. You know when you're in the hospital and maybe you're pregnant? They have that thing in the hospital and when it goes straight, it means you're not being good. Like, you're very sick. That means signs of life there. But, it's different for a musical instrument so I guess [the oscilloscope] was just showing what notes she was playing.

Although Victoria was the only child to explicitly demonstrate this creative, imaginative approach to the teacher's science, we must wonder if this approach was also taken by other children. Perhaps one difficulty other children might have had with revealing this creative approach could have resided with my questioning. Asking the children for their explanations of the science could result in the children providing their final explanations and telling me what influenced their ideas, and at the same time excluding the entire process which resulted in their explanation. Also, it is difficult to recall and repeat what was probably a rapid, imaginative sequence of thought. Further, perhaps the children ruled out this creative element as a viable part of explaining science, especially if they felt that the school system only required and rewarded their final explanations. Regardless of the reason for what could be the children's reticence about revealing this creative element, Victoria's comment establishes that it did exist, and we can wonder about its prevalence.

This recognition of a creative element in making links, and the importance of links in the children's struggle for understanding, leads to an examination of instances when the children spoke about the actual links they made during the Sound unit. The factors which influenced these links are summarized in Table 8.

b) Linking With the Child's Homelife

The children frequently referred to experiences from their homelives which seemed similar to some aspect of the teacher's science, and they used this knowledge to help them interpret the lesson. Some of the links they made aided their understanding of the teacher's science, while other links seemed to have the potential to cause future difficulty. Also, the children tended to refer to

TABLE 8

Factors Influencing the Children's Construction of Links to Existing Knowledge

A. Factors Related to the Teacher's Presentation of the Lesson

1. Use of a similar phrase
   e.g., small bits of matter - small bits of something

2. Use of a situation which requires similar conditions
   e.g., bells need air to ring - people need air to breathe

3. Use of a familiar topic or concept
   e.g., amplification; ear infections; hearing distant sounds

4. Use of identical words
   e.g., vibration; energy

5. Use of similar sounds
   e.g., sounds in a railway track - sounds in a volleyball pole

6. Use of similar activities
   e.g., lines of girls - lines of boys

7. Use of activities which have similar explanations or underlying concepts
   e.g., pitch is related to how fast a stick, comb, or bicycle wheel is moving

B. Factors Associated With the Children

1. Variety of past experiences

2. Intellectual ability or maturity
   e.g., reliance on identical objects, actions, or vocabulary to make connections

C. Factors Associated With the Research Design

1. Interview situation may be tedious for the child

their homelives with greater frequency towards the beginning of the Sound unit; as the unit progressed, they were more likely to attempt to link the teacher's science to information they had been exposed to in previous science lessons.

On November 13th, Bob struggled with the idea of molecules, and then wondered if a previous conversation with his brother could assist him in understanding this concept.

> B: The air, there is stuff in it. My brother told me that once, like he told me, I forget what they're called. . . . He said in the car there is all this dust that we breathe and there are little things floating. He said they were molecules or something. I'm not sure.

In this comment, Bob implies that the teacher's description of molecules as being 'small bits of matter that are so small they cannot be seen' reminded him of other 'small bits of something' which his brother described as being in the air. This might imply that the teacher's use of a phrase which is similar to a phrase with which the child is already familiar, may give rise to the formulation of a link between the teacher's science and what the child already knows.

During the November 19th lesson, Victoria viewed a film in which air was removed from a jar in which a bell was suspended. Consequently, the children could no longer hear the bell even though the clapper continued to move. Victoria explained

> V: But, maybe it has something to do if you take away [air], with a bell and smoke, eh? And there's no more air, [the bell] stops. Sort of like us. We stop breathing when there's no more air.

Victoria links the bell demonstration to her prior knowledge about breathing, and she draws a parallel between breathing and ringing bells. Perhaps this is due to Victoria observing that air seemed important to the demonstration and relating this observation to another situation where air seemed important. This might imply that the teacher's presentation of a demonstration which required conditions similar to the conditions necessary for another phenomenon, can give rise to the formation of a link between the teacher's science and what the child already knows. In a later lesson, the teacher performed this demonstration for the children and Victoria maintained that the clapper should have stopped moving because all the air had been removed.

> V: . . . because it is like your heart. When you stop breathing, your heart stops.

In this example, Victoria's obvious linking of the teacher's science to her homelife resulted in a situation that could stand to affect her potential understanding of, and consensus with, the teacher's science.

Another situation which arose during the teacher's presentation of the science involved times when children interrupted her to relate stories which they perceived to be related to the lesson. Although these stories arose in many lessons, they seemed particularly numerous on November 17th when the teacher dealt with the question, 'How do we hear?'. During this lesson, the children told stories about ear infections, various ear diseases, people they knew who had hearing problems, and friends who had tubes placed in their ears. Although these stories could delay a lesson, and perhaps lead to concerns about available time, they do represent attempts by the children to relate the teacher's science to their homelives; Barnes (1976) maintains that the "[child's stories] constitute his [or her] starting point, the source of the understanding which he [or she] will bring to [the teacher's science]" (p. 117).

In addition to instances when the children related the teacher's science to their broad range of homelife experiences, there were times when the children linked the lesson to some of the ideas about sound they held prior to the commencement of the Sound unit.

c) Linking With the Child's Initial Ideas

The children's initial ideas about sound could both assist and hamper their ability to accept and potentially understand the teacher's science.

Victoria was confident prior to the commencement of the unit that sound travelled by vibrations which she described as being 'imaginary lines capable of floating through the air.' During the November 10th lesson, the teacher introduced the term vibration and Victoria was able to link this term with her prior use of the term vibration, and consequently defined vibrations as 'imaginary lines.' Additionally, on November 12th Victoria noted that her sound system could amplify sound and she integrated this information with her prior ideas of amplification and concluded that sound could also be amplified by

> V: . . . having a bigger thing. And [sound] can get loud by an echo. Like in the mountains when you yell something, together it all sounds loud.

These examples reveal that the teacher's use of an identical word (e.g., vibration), or her presentation of a familiar concept (e.g., amplification), resulted in Victoria being able to make links between her prior ideas and the teacher's science which could potentially help or hinder her future understanding of some of the science concepts.

There were instances, however, when the children's prior ideas about sound seemed to take precedence over the teacher's science and perhaps prevented the children from arriving at greater understanding. On November 13th, the teacher introduced the term energy and related it to the idea that 'molecules lose a bit of energy each time they pass on a force.' However, Victoria, Gordon, and Samantha made no reference to this alternative definition of energy, and instead repeated their initial ideas about energy being related to plugging appliances into wall outlets, using batteries, eating food such as sugar, getting energy from sleeping, and needing energy to move. The children's answers may suggest that at times they held onto their prior ideas with great tenacity, or that they simply found the teacher's science to be incomprehensible, or that their own ideas seemed more sensible and concrete than the teacher's science. Regardless of why the children repeated these definitions, it still stands that the teacher's use of a word which was identical to one they had previously defined, resulted in the children formulating links between the teacher's science and what they already knew.

d) Linking to Other Subject Areas

On November 13th, Mrs. L mentioned as a minor point in the lesson that her inability to hear distant objects was the result of energy 'wearing out.' However, Gordon arrived at the opposite conclusion that it was possible to hear distant objects, and he referred to the influence of his experiences in gym class.

> G: Well, I believe that you can hear things farther away 'cause all the kids, when they take up all the Newcome nets, we always go down to the far one and [we] . . . can still hear the bell loud and clear.

This comment, like the children's definitions of energy, might again suggest that experiences from their personal lives can outweigh the teacher's science, and could result in the children coming to possess a variety of alternative ideas about the science. Also, this example reveals that Gordon made a link between the teacher's statement about hearing objects and an experience in his life where he has the opportunity to hear distant objects, and this allowed him to make a judgement about the believability of the teacher's science.

In contrast to the outcome of Gordon's thinking was Victoria's reaction to an aspect of the film which she viewed on November 19. In this film, a boy used a stethoscope to listen to sounds travelling through a railway track. Victoria related the sounds the boy heard to similar sounds she had heard in gym class while swinging around the poles which supported the school's volleyball net.

> V: I was swinging around [the pole] and my friend had her ear to the pole on the other side. She could hear the screeching of me. And then she did it and I could hear her. It had something to do with that. Vibrations go through over to the stethoscope.

Again, Victoria's recognition of a sound with which she was already familiar allowed her to make a connection to the teacher's science which potentially could assist her in coming to a personal understanding of the science.

e) Linking to Other Sound Lessons

During the Sound unit, Mrs. L introduced concepts and ideas which were explored in several lessons, and which formed the background for explaining future activities and demonstrations. Therefore, it was important that the children should perceive links between lessons because Mrs. L planned that these links would form a basis for understanding the Sound concepts.

As the Sound unit progressed, the children were more likely to attempt to interpret the teacher's science by making links between the new science, and the science they remembered from previous Sound lessons. Unlike the links the children made to their homelives, to initial ideas, and to experiences in other subject areas, it seemed that the children were more willing to modify or discard their newly acquired ideas about sound than they were willing to change their minds about their initial ideas. Also, their newly acquired science ideas seemed to result in the children increasingly anticipating the results of the teacher's demonstrations and activities, and this sometimes led to the children displaying a variety of ideas about the science. Finally, the children would sometimes use ideas in the present lesson to explain and expand upon science ideas from previous lessons. In this way, not only were the children making connections between ideas presented in the Sound unit, but these connections were characterized by an oscillation which allowed the children both to anticipate the science and to explain earlier ideas.

i) Linking to Other Lessons

On some occasions the children would link the current lesson to former lessons and this could result in the children experiencing a sense of conflict and confusion. On November 19th, Bob watched a film which showed a diver ringing a bell but found this confusing because he recalled from a previous lesson that a bell suspended in a jar required the presence of air before he could hear the sound of the bell. In this lesson, he observed that the underwater bell obviously rang in the absence of air. Bob concluded that he was puzzled about this apparent conflict.

On other occasions, the links the children made to other lessons could enhance their understanding of the lesson. During the November 13th lesson, the teacher presented demonstrations involving marbles, Slinkies, and lines of children. Afterwards, Bob related these new ideas to the lesson in which he assembled a sound system, and remarked that molecules must also be involved in amplifying sound.

> B: Kind of when we used cups, the sound travelled from the elastic. The molecules travelled into the cup and made a sound.

This comment implies that Bob was able to link an explanation from the current class to another situation in which he reasoned that sound also had to be travelling.

In this same lesson, Christa recalled the teacher's previous instruction involving vibration, movement, and force and summarized:

> C: Everything has some kind of movement. There was the vibration which was the movement, and there was the push which was the movement. You needed some kind of force. The movements were all fast.

This comment implies that Christa was able to make links between elements of different lessons, and could form generalizations about the teacher's science.

These comments by Christa and Bob demonstrate the intelligent and impressive thinking of which the children were capable. Certainly, the links made by the children establish that they were actively trying to understand and personalize the teacher's science.

During other science lessons, the teacher's use of activities which were similar to those presented in previous lessons allowed the children to identify links between lessons. Probably the most obvious example arose during the November 17th lesson when all the children recognized that the demonstration involving lines of boys paralleled the teacher's previous demonstration with a line of girls. A more challenging example was contained in the November 20th lesson when the teacher orchestrated a playground demonstration of the speed of sound. At that time, only Christa and Samantha recognized that this demonstration was similar to the demonstration they viewed in a film during the previous lesson.

> C: We did more or less the same thing [as we saw on the film]. We learned about the sticks which was more or less exactly the same as the gun.

This latter example may imply that such factors as the child's intellectual competence or maturity could affect his or her ability to make connections between lessons which required more than just recognizing obviously similar demonstrations. Certainly in this study, Christa, Bob, and Samantha were more likely than Victoria and Gordon to comment about connections between lessons which required the identification of common themes, the application of new information, or the recognition of events which were similar but not identical. Perhaps by examining instances when the children were unable to link together sound lessons we can gain more insight into this phenomenon.

ii) Seeing the Lesson as an Isolated Event

Victoria and Gordon were most likely to encounter difficulty with perceiving connections between lessons in the Sound unit. Their difficulties first came to light in the November 9th science class when they both claimed that this lesson seemed separate from other lessons. Victoria reasoned that the use of a piece of paper to make sounds in the previous lesson, and the lack of paper in the current lesson, demonstrated that the lessons were unrelated. This comment was the first indication that Victoria's ability to make connections between lessons could be influenced by the actual objects which were used in each class. Gordon thought the November 9th lesson was separate because not only did he fail to see a connection, but like his difficulty in perceiving the purpose of the lesson, he "could not read the teacher's mind" to see if she had intended a link. This suggests that he was also experiencing difficulty perceiving the overall unit structure and had somehow missed the significance of the teacher's review of the previous lesson.

On November 10, Victoria repeated her rationale that the lesson was separate from other lessons because of the use of different objects. Gordon reasoned, however, that the lesson was separate because the elastics in the previous class did not vibrate while today's tuning fork did vibrate. Perhaps at this time Gordon was able to associate the term vibration only with the object which the teacher used to introduce the term, and I wondered if he would eventually expand his definition to include a range of objects.

After the November 12th lesson, Victoria offered comments which seemed to reinforce the idea that she relied on obvious congruities to make links between lessons. In this lesson, Victoria stated that she recognized connections to other lessons because she had already used tuning forks and hockey pucks, and the pulling action she made on the elastic band was identical to actions she had done in previous lessons. Gordon also identified the use of identical objects as being an indication this lesson was connected to other science classes.

At this point, it seemed obvious that Victoria, and to some extent, Gordon relied on the inclusion of identical objects, actions, and vocabulary to draw connections between lessons in the Sound unit. However, on November 24th when the children participated in the tin can telephone and rubber hose activities, all five children seemed to experience some difficulty in identifying how this class was connected to previous lessons. Christa simply offered that today's class also dealt with sound, and Samantha reasoned that there must be a connection because this was a science class. However, Samantha added that she was unsure about the nature of this connection because she had never used tin can telephones and a rubber hose in any other class. Bob did not identify any connections, and Victoria commented that although tin can telephones did have something to do with vibration, today's class seemed separate because they had never before used tin can telephones. These comments might suggest that for some children, perhaps the novelty of the objects interfered with their ability to make connections between this and other science lessons. Also, children who had previously offered complex answers about connections between lessons could also experience difficulty identifying connections between other lessons. I further wondered if the children's answers were in part influenced by the interview situation. The children had participated in the lesson during their first period in the morning and their interviews took place in the afternoon. I wondered if the length of time that had passed, my repetitious questions, and the length of the interviews were becoming tedious for the children.

These comments establish that for the children in this study, the inclusion of identical or similar objects, situations, words, and demonstrations could be important factors in their ability to make connections between lessons in the Sound unit. The links that they made could result in the children maintaining that the lessons were unrelated, related, confusing, or understandable. The final kind of link the children made involved making connections between demonstrations and activities contained within the same lesson.

f) Linking to Concepts and Tasks Within the Same Lesson

Frequently, the teacher included a number of related tasks within the context of a lesson, and it seemed important that the children perceive commonalities between these tasks in order to move towards an understanding of the entire lesson.

On November 30th, Christa participated in activities involving running a card over a comb, "twanging" a stick, and holding a card against a spinning bicycle tire. She was able to perceive commonalities between these activities and summarized them this way:

> C: Well, with the comb, [the movement] was fast, and [the sound] is high. So, I guess, [in regard to the stick], it's like, the shorter [the stick], the higher the pitch, [and in regard to the bicycle], the faster [the wheel spins], the higher the pitch.

However, there seemed to be more instances when the children experienced difficulty perceiving themes and commonalities within a lesson. On November 10th, Gordon used the term vibration to explain the movement of his tuning fork but he did not use this same word to explain the appearance of lines on the surface of the water within which he had dipped his tuning fork. On November 26, Bob observed that sounds were louder when he listened with his ear on the table, and he explained that he thought this was because 'sound travels faster through solids.' However, he did not use this explanation to explain the louder sound he heard through the air register and admitted that he found this activity to be puzzling.

> B: I'm not really sure about that. I don't know. Maybe because you have your ear closer to [the air register] or something.

Driver, Guesne, and Tiberghien (1985) have also observed children's difficulties with applying the same explanation to more than one demonstration, and they have offered that this is an example of context dependency. They reason that children can utilize a variety of explanations to "interpret situations which a scientist would explain in the same way" (p. 196). Like the children's comments about connections between lessons, this phenomenon also has some obvious implications for science teaching.

g) Summary Discussion

The children in the study were capable of making an overwhelming number of links between the teacher's science and what they already knew. This observation is in contrast to Biddulph's (1982b) classroom research on children in science where he claimed that "there was little real linking of new knowledge to the ideas already held by children" (p. 4), and that "differences rather than similarities between objects and events caught [the children's] attention" (p. 10). What could be said about the children's comments in this study is that although the children noticed the unfamiliar and novel, they frequently used the familiar to make links to what they already knew.

This 'linking with the familiar' depended upon situational factors such as the words the teacher used during the lesson and the nature of the tasks and demonstrations, and depended upon cognitive factors such as the content and scope of the children's prior knowledge about sound, and the children's intellectual abilities. Sometimes the teacher had to use identical words (e.g., vibration), actions (e.g., pulling), or objects (e.g., paper), while on other occasions the use of similar phrases (e.g., small bits of matter), and demonstrations (e.g., lines of girls) could result in the children making links between the teacher's science and what they already knew. Some children possessed the clarity of vision which allowed them apparently effortlessly to perceive complex and insightful connections between ideas and lessons.

> C: All of the [objects] had a vibration. The pop bottles had the air, the beakers I guess had the beaker vibrate, or something, the comb had the teeth, the wheel had the card, the stick had the stick, and the elastic on the box had the elastic vibrating. They all had something vibrating.

Other children were more perceptually dependent and at times found it difficult to make connections because of their apparent dependency on the use of identical words, objects, and actions.

> V: There was no connection because we didn't hardly use any metal yesterday. And today we used metal.

Also, there existed more of a creative element to the children's connections than what appeared in their comments and further exploration into this imaginative element might provide clues that could assist in interpreting links children make.

The children's comments about links and their previous comments about defining the new fact show that as the children related the teacher's science to what they already knew, they began to construct personal meanings of the teacher's science. For example, when Victoria concluded that the teacher's marble demonstration showed that marbles could make sound, or when Gordon reasoned that tuning forks did not vibrate, these ideas formed a part of the personal meanings they were constructing for the teacher's science which was presented in those lessons.

At the beginning of this chapter, however, the children's struggle for understanding was likened to a stranger approaching a new culture, and I offered that the stranger's experience involved not only relating new information to what he or she already knew, but could also involve the emotions and personality of the stranger. Therefore, maybe when Victoria concluded that the teacher's marble demonstration showed that marbles could make sound, or Gordon reasoned that tuning forks did not vibrate, these ideas could also say something about the children themselves, and how their personalities and philosophies intertwined with their intellectual abilities and situational factors to influence the nature of their personal meanings of the teacher's science. This complex and challenging hypothesis is explored in the following section.

3. Constructing Personal Meanings

The formation of links allowed the children to construct "tentative meanings . . . prior to the final construction of meaning" (Osborne, & Wittrock, 1983, p. 494). This process of constructing tentative meanings is close to Schutz's (1971) description of a stranger 'translating' the new culture into terms of "the cultural pattern of his [or her] own group" (p. 99). Schutz (1971) adds that several factors supervene in understanding a new culture. First, words and sentences used by the new culture have a "halo of emotional values and irrational implications which themselves remain ineffable" (p. 100). Also, any language contains terms with several connotations and words may acquire a "special secondary meaning derived from the context or the social environment within which it is used" (p. 101). Finally, specific social groups use idioms, technical terms, jargon, and dialects which also must be learned by the approaching stranger. In this study, the process of constructing meaning for the new culture of the teacher's science could result in a variety of outcomes including retaining prior ideas, modifying the teacher's science, extending and modifying existing ideas, and changing ideas.

When Mrs. L and I read the children's interview transcripts and discussed the variety of reactions the children had to the teacher's science, it seemed to us that the children's ideas and comments were imbued with the personality and intelligence of each individual child. In our conversations we referred to this apparent blending of the cognitive and affective as the 'personal' or 'unique' element that seemed to underlie all aspects of the children's struggle for understanding. For example, Mrs. L and I observed that some children experienced occasions when they accepted and repeated the teacher's science -- simply, they said, because it was presented by the teacher. We wondered if their acceptance arose out of a faith in adults, or a sense of loyalty towards the teacher, or their philosophy of school, or their locus of control, or a sense of security associated with just accepting the teacher's science, or a lack of motivation to construct their own learning, or a recognition that they had difficulty comprehending the science concepts.

Some of these factors draw attention to the personal nature of the children's struggle for understanding, and how affective factors could stand to influence the meanings they constructed of the teacher's science. There has been a recognition that affective factors integrate with cognitive factors in a child's attempt to evaluate and understand the teacher's science (Head, & Sutton, 1981; Koestler, 1976; Pope, & Gilbert, 1983a). Perhaps this integration can be better illuminated by examining some of the outcomes of the children's translation and construction of personal meanings, and by discussing what affective factors might have influenced these outcomes.

a) Holding on to Prior Ideas With Tenacity

Driver and Erickson (1983) have commented that children's prior ideas about a science topic are "strongly held and resistant to change" (p. 41), especially if they are built on a physical or linguistic experiential foundation. In the previous section of this chapter which dealt with the kinds of links the children made, the children frequently implied that their prior ideas were based on an experiential foundation, and when I compared these prior ideas to the many ideas they offered about the teacher's science, it seemed the children were less likely to change their prior ideas, and more willing to discard and modify their evolving ideas about the science lessons. This may appear curious because the children frequently participated in hands-on classroom activities which were intended to provide an experiential foundation for the teacher's science. Perhaps this calls into question whether the ideas which emerged from the children's participation in the science class were qualitatively different or less meaningful than the ideas which the children derived from situations in their everyday lives.

In their initial interviews regarding their prior knowledge about sound, Victoria, Bob, and Samantha commented that movement was not a necessary requirement of sound. In light of Mrs. L's emphasis during the October 27th lesson on how the children had to do something to make sound, I questioned the children about this aspect of their initial beliefs. All three children were able to rationalize Mrs. L's statements about movement by reasoning that she was specifically talking about the paper and movement, and she was not thinking of the variety of objects in the world which make sounds and obviously do not move. Simply, although they did not reject the truthfulness of the teacher's science, they did think that it was narrow in scope and displayed limited applicability. As Bob said

> B: She probably thinks of what she was doing. She was moving, everything she did, things were moving.

In this lesson, it seemed that the objects several children brought from home, the ten sounds presented by the teacher, and the manipulation of the piece of paper, were not sufficient to change Victoria's, Bob's, and Samantha's initial ideas. It seemed that perhaps only examples and activities that were specific to those offered by these three children in their initial interview might have changed or modified their prior ideas, or maybe something more personal had to happen before they would relinquish their hold on their prior ideas, or attempt to incorporate the teacher's science into their system of beliefs.

Schutz (1971) proposes that the stranger may perceive the new culture as a menace to his or her "thinking as usual"; other authors have offered that there is an element of risk involved in leaving the security of the known, and beginning a struggle towards some new understanding (Claxton, 1984; Maslow, 1966; Smith, 1987; Solomon, 1983). Smith (1987) writes:

> To take a risk requires that the 'unknown' be encountered - that we do indeed experience uncertainty. We are required to do more than what feels comfortable, more than simply display those 'capabilities' we have. We must dig deep within ourselves and test the limits of our resources. Taking a risk is the project of encountering the 'unknown' wherein self-understanding occurs. (p. 64)

Claxton (1984) warns that a child may find it threatening to give up existing ideas because he or she may have a personal identification with the knowledge. Therefore, if Claxton's hypothesis is correct, giving up an existing idea may be comparable to giving up something of oneself, and this could represent a threat to the child's social stability, and possibly result in the child either retaining his or her prior ideas, or being more likely to modify the teacher's science to render it compatible with existing ideas.

Solomon (1983) adds that another way a child may cope with the implied threat of change is to develop two domains of knowledge which the child then moves between. One domain may consist of the everyday notions the child uses to explain his or her world (e.g., movement is not a requirement of sound), and the other domain may contain the scientific explanations associated with the teacher's science that the child may use to explain classroom science (e.g., you have to do something to make sound). This could result in a child who retains his or her prior ideas and stores the teacher's science alongside, and quite separate from, these prior ideas.

If there is an element of risk involved in giving up prior ideas, or being willing to encounter new ideas, then this may imply that children who are brave in their thinking, or confident in their ability to think, may be more likely to modify, expand, or supplant their existing ideas. However, when Mrs. L and I studied the children's interview transcripts it seemed to us that although some children appeared more willing to expand and modify existing ideas, these same children were quite capable of showing considerable resistance to other new ideas. This may suggest that a child might sometimes feel anxious about new ideas, and on other occasions might feel neutral, or even challenged to confront and make sense of the new ideas. Perhaps this range of reactions that any one child could have towards the teacher's science emphasizes that a child's willingness to retain, modify, expand, or supplant an idea is influenced by a combination of cognitive, affective, and situational factors.

As the Sound unit progressed, some of the children's prior ideas, and the ideas they garnered from the sound lessons, were modified or expanded to incorporate various aspects of the teacher's science. Furthermore, the children were quite capable of modifying the teacher's science so that it would support both their prior ideas, and ideas from previous lessons about which they still felt unsure. To add to this complexity, on one occasion Gordon seemed to take a sudden leap in which he discarded his initial idea and immediately adopted a new idea.

During this overwhelming number of modifications, apparent changes, and frequent reversals, it was often difficult to assess how cognitive, affective, and situational factors were combining to influence the children to give the answers they offered. At times it seemed that the children did progress through Hewson's (1981) attributes of change, but during many moments it appeared that the apparent change in their ideas was only tentative, and part of the mosaic of evolving ideas which the children considered during the Sound unit. Perhaps by examining some selected examples of the children's attempts to integrate some of the teacher's science into their own ideas, we can gain some insight into the intelligent, tangled, and mostly experimental web of ideas which the children wove as they struggled towards a personal understanding.

b) Modifying the Teacher's Science to Fit Existing Ideas

Perhaps the most outstanding example of a child gaining some knowledge during the science unit, and then modifying the teacher's science to support this knowledge was displayed by Victoria during the lessons of November 24, 26, and December 1.

During the November 24th lesson, Victoria had the opportunity to yell through a tin can telephone and a rubber hose. After this lesson, she explained that she could hear sounds better through the hose because not only was the hose wider than the string of the tin can telephone, but the hose also contained a hollow space which was bigger than the hollow in the string. She based this explanation on her previous knowledge that sound travelled in the form of sound waves, and obviously those sound waves relied on the presence of air. Victoria's explanation seems only reasonable in light of the children's prior exposure to ringing tuning forks, and the bell and jar demonstration.

During the November 26th lesson, however, the teacher presented activities and demonstrations intended to support the idea that sound could also travel through a solid and that, when compared to air, sounds were louder through a solid. Victoria participated in all of these activities and observed that when she held her ear on the table, the sound was louder than when she held her ear over the table. However, she explained that the sound was louder because the table was hollow, and she added that she was aware of the hollow construction of tables because tables were similar to the clay objects she had sculpted and fired during art class.

> V: I think all the tables are hollow except for our table at home. . . . Do you know why tables are hollow? I think some of the tables are spray painted and they are hot and you have to have some air. Like, when we have art you have to dig a little hollow in here at the bottom of your [sculpture] because it might explode.

On December 1, the children viewed a film which showed that animals could hear through solids such as soil. On the surface, it seemed that this conflicted with Victoria's ideas about the necessity for hollow spaces, and could potentially influence her to change her explanation. However, Victoria explained that rabbits could hear approaching predators because the sound travelled down the hollow tunnels of their burrows.

This example makes clear how Victoria formed an initial perception about how sound travelled, and then threaded together, and modified aspects of the teacher's science to support her initial perception. It does not appear that Victoria recognized the conflicts between her own ideas and the teacher's science, nor does it appear that she possessed doubts about her personal explanation of the science. Instead, she appeared quite confident in her reasoning and perhaps we can assume that she still retains this explanation.

Why did Victoria continue to maintain that sound could only travel through hollow objects while other children all offered explanations about sound travelling through solids? One explanation might lie with Victoria's conception of a solid. Mrs. L suggested that children may have difficulty understanding that string is a solid because they might associate the term solid with objects which are hard and rigid such as a desk. In a subsequent interview, I questioned Victoria about solids and she explained that there were two kinds of solids: (1) solids which are hollow (e.g., some tables), and (2) solids which are solid (e.g., walls and floors). By using this personal system of categorizing solids, Victoria was able to retain her own idea (e.g., sound travels through hollows), and yet incorporate vocabulary from science class (e.g., sound travels through hollows, and some solids are hollow).

Another reason for Victoria's explanation that string was a poor conductor of sound could lie with her perception of the physical appearance of string.

> V: [It is hard to believe that vibrations go through a string because] the string is so narrow. The string is so skinny.

When I asked Victoria what would convince her to believe that vibrations could travel through a string, she answered that if a scientist told her that information, then she would believe. These comments reveal that Victoria found some aspects of the teacher's science to be so amazing and counterintuitive that the science was unbelievable. Additionally, the teacher's statement that sound travels better through solids such as string was not borne out by Victoria's personal observations of yelling through a tin can telephone, and this probably enhanced Victoria's feelings of disbelief.

In this example, Victoria thought that she would only believe if a scientist corroborated what the teacher had presented. This implies that Victoria would be willing to mentally accept the concept because of the authority she associated with a scientist, but it still does not assure us that Victoria would feel a sense of certainty about the concept, or if she would abandon her own personal explanation of the concept. This suggests that as children construct meanings for the science, they may judge, evaluate, and modify the teacher's science, and this process of deliberation involves making observations, generating links, judging the believability of the concept, and formulating meanings which seem to provide a satisfactory explanation. Sometimes these explanations may be influenced by the child's perception of authoritative sources of information, and perhaps we can wonder if children who are taught at home to listen to adults and accept the authority of adults might be more prone to (a) recall and repeat the teacher's science; or (b) supplant their own constructed meanings with the teacher's science; or (c) retain a science which they believe, and develop another science which they use for science tests and quizes.

c) Modifying Existing Ideas

In addition to children being willing to modify the teacher's science were numerous instances when the children modified or expanded upon their own existing ideas. During the interview regarding her prior ideas about sound, Christa claimed that her ability to hear through a solid was dependent upon the thickness of the solid. Then, during the November 19th lesson, she watched a film in which a boy struck a railway track with a hammer, and she concluded that although she still thought the thickness of the solid was important, the boy's demonstration showed that "sound goes ten times faster through steel." On November 24th, Christa listened to a tin can telephone and observed that she could not hear sounds very well. She then concluded that not only was the thickness of the solid a factor in her ability to hear, but the sound she heard was also influenced by the material of which the solid was composed. However, she was not convinced that sound travelled faster in solids than in air.

> C: Well, for some reason I think that sound travels faster in air than solids, except for steel, metal, and that sort of stuff.

In this example it seems that Christa was aware of the teacher's science (e.g., sound travels faster in solids), but only chose to modify her existing ideas if the teacher's science was borne out by her own observations. This is reminiscent of Victoria's reaction to the tin can telephone in that Victoria's disbelief seemed, in part, to be influenced by the fact that her observations did not support what the teacher had presented in class. This may suggest the importance of allowing children to make their own observations, and how these observations affect the children's perceptions of the believability of the science, and affect the meanings they construct of the teacher's science. Also, for Christa, the opportunity for personal, first-hand observation was an important factor in her willingness to change or modify her existing ideas.

On November 26th, Bob stated that he no longer agreed with his initial idea that his ability to hear through a solid was dependent on the thickness of the solid. Instead, he now thought that hearing through a solid was a function of how hard the solid was hit, and he changed his mind one night at home while he was thinking about his science classes.

> B: I kept on thinking about sound, everything we did. Then I got stuck on one thing, [the thickness of the solid]. And I thought of it, and I thought of it, and I got the answer.

This comment shows that Bob recognized conflicts or gaps in his understanding of the teacher's science, and through reflection and reconsideration he modified his existing idea. Posner, Strike, Hewson, and Gertzog (1982) describe this process as involving (1) the recognition of an anomaly, (2) the belief that it is necessary to reconcile the anomaly into existing conceptions, (3) a commitment to reducing inconsistencies among existing beliefs, and (4) a recognition that former attempts to assimilate have been unsuccessful. This process, and Bob's comments, suggest that a combination of cognitive, affective, and situational factors influenced Bob to modify his idea about hearing through solids. In class, Bob listened to tapping sounds as the sounds travelled through the table and air register, and he observed that if these objects were struck with more force, then he heard a louder sound. Therefore, it seemed only reasonable for him to conclude that the action of tapping, rather than the thickness of the solid, was the crucial factor in his ability to hear the sound.

Posner, Strike, Hewson, and Gertzog (1982) maintain that such issues as motivation and commitment are also involved in modifying existing ideas. In this study, the motivation to reconcile personal meanings with the teacher's science, to understand the teacher's science, or to at least recall and repeat the teacher's science, seemed to be influenced by external and internal factors. Some of the external sources the children identified were the responsibility they felt towards completing worksheets, writing examinations, and responding during their interviews.

Both Bob and Gordon recognized the importance of completing worksheets, and after the November 10th lesson in which Mrs. L demonstrated a vibrating tuning fork, Bob reasoned that

> B: [The teacher demonstrated] that for us so that after when we do the [worksheet], we could do [the worksheet] easier.

Also, Bob commented on the importance of knowing the teacher's science because he would eventually be expected to write a unit quiz. This may suggest that Bob's motivation to reflect upon his classroom observations and how these observations might challenge his existing ideas, in part, could have been derived from his awareness of impending formal evaluations.

Another source of external motivation was identified by Victoria during the November 13th lesson, when she revealed that she was unsure about how to answer one interview question and had therefore spent time researching the question so that she would be better able to provide an answer. On November 17th she anticipated that I would ask her about the purpose of the lesson and she admitted that she reflected upon this during the science lesson. Later in the science unit, when I asked her what she had learned from a lesson she replied

> V: I always know we are going to have that question so I thought about it and I have a good answer, I think.

These comments establish that the children could be motivated by a number of external sources, but it does not seem clear if this external motivation played a significant role in either encouraging the children to recall and repeat the teacher's science, or to reconcile their meanings with those of the teacher, or to strive towards a meaningful understanding of the teacher's science.

In addition to these comments about sources of external motivation were many more instances when the children's comments suggested that their motivation was derived from a concern for personal coherency. This is not to claim that this apparent concern for coherency could not also be subject to an overriding concern about exams and worksheets, but rather that it seemed the children 'forget' these external factors and were legitimately trying to understand the teacher's science because they wished to possess a more coherent view of the world. Again, Bob's description of reflecting upon his classroom observations could have been an expression of his concern for personal coherency, and not simply a reaction to his perception of external sources of evaluation. Further, the children's willingness to admit that they wondered about the science, and their ongoing struggle to construct personal meanings for the teacher's science, suggest that they were concerned about constructing meanings which they believed, understood, and about which they felt confident.

Wittrock (1986) has addressed the issue of motivation and argues that if students believe that the effort used in struggling towards a personal understanding of the teacher's science is directly related to success, they will be more likely to be motivated towards this effort. If, however, a student attributes school success to the ability to recall and repeat the teacher's science, then he or she may be more likely to concentrate on memorizing the teacher's science, and be less concerned with integrating this science into their present ideas. These observations imply that if a child believes that learning is dependent on external influences, and observes that the school system rewards the ability to recall and repeat the teacher's science, the child might be less likely to pursue a personal understanding of the teacher's science.

Posner, Strike, Hewson, and Gertzog (1982) also offer that the process of modifying existing ideas involves the issue of commitment. In this study, commitment to the questions being explored during science class emerged as a potential motivating factor. Christa alluded to this issue on November 17th when she commented that the teacher included a lesson on 'How ears hear' because this was probably the main question children had about sound. Barnes (1976) comments that motivation may in part depend on whether the child finds the subject under study to be meaningful, and perhaps Christa's identification of children's interest in 'How ears hear' implies that children may be more motivated to explore questions which obviously relate to themselves and their world. Osborne (1985) adds that children who are "encouraged to ask genuine questions that they have about things . . . [and] are helped to undertake relevant investigations to find answers to these questions" (p. 19), are more likely to maintain their thirst for learning about things in science, and strive towards constructing personal meanings. Perhaps Bob's willingness to modify his existing ideas was, in part, influenced by his perception that the question, 'What factors affect how we hear through solids?', was a question that was meaningful and related to his world.

Related to the issue of motivation is the child's willingness to take responsibility for his or her learning. If a child is for some reason unwilling to take such responsibility, then it seems likely that he or she would either make little effort to attend to the teacher's science, or might be content to recall and repeat the teacher's science. In this study, the children's comments, and the persistence they displayed trying to understand the teacher's science, suggest that the children were for the most part willing to take responsibility for their own learning. This sense of responsibility was, in part, probably a result of their parents' successful attempts to convince the children of the importance of good work habits, and to instill in them a vision of the eventual payoff of success in school. Certainly, Bob's parents possessed the philosophy that hard work and determination led to success, and if Bob believes this philosophy, then it does not seem surprising that he would spend time outside of the science classroom reflecting upon the events of the class, and trying to construct a more coherent understanding of the teacher's science.

In summary, the children's willingness to modify their existing ideas was influenced by a combination of situational, cognitive, and affective factors. In class, their opportunity to participate in the activities, make personal observations, participate in class discussions, and listen to direct instruction affected the meanings they constructed. The children's ability to make accurate observations, perceive connections between activities, and recall and reflect upon classroom events, could also affect their constructed meanings. Finally, the children's sense of responsibility, commitment, and even their personal motivation might influence the meanings they constructed, and their willingness to modify, expand, or perhaps even change these constructed meanings.

d) Sudden Change

The majority of the changes and modifications the children made to their ideas in this study had a traceable history. This history may have involved their reactions to films, demonstrations, class discussions, and hands-on activities, and included the process of reflection and deliberation which occurred during and after these classroom events. When the children's comments, and my description of the science lesson were combined with Mrs. L's and my knowledge of the background and personalities of the children, tentative hypotheses about what influenced the children's explanations could be presented.

There was an instance in this study, however, when a child changed his existing idea and this change did not seem to be preceded by an extended process of reflection and deliberation. After the November 19th film, Gordon claimed that he no longer agreed with his initial idea that it was impossible to hear through walls because they blocked sound. When I questioned him about what part of the film had influenced him to change his mind, he replied that he had just at that instant changed his mind because he could hear the janitor vacuuming the hallway outside of the closed door of the interview room. Sutton (1980) states that students "frequently report such moments of insight" (p. 119), and that this has been called the 'penny dropping' or 'clicking' phenomenon. Sutton (1980) suggests that any model of change should allow for this phenomenon, and Gordon's comment supports the idea that recalling prior ideas and then examining these ideas at crucial or opportune moments could also be a factor in the modification or expansion of existing ideas.

On November 26th, however, Gordon once again claimed to have just changed his initial idea that it was impossible to hear through walls because they blocked sound. This time, he maintained that the opportunity to listen through solids in today's lesson convinced him that it was possible to hear through solids such as walls. I wondered if his former claim to change on November 19th was a fleeting change, or whether he simply had forgotten his previous statement. Regardless, the idea of the existence of opportune moments to change an idea, might be an idea worth considering for its potential influence on models concerned with explaining how and why children retain, modify, and expand their ideas.

e) Summary Discussion

The children's comments about making observations, perceiving connections between lessons, generating links between the teacher's science and what they already knew, and constructing meanings for the teacher's science establish that situational, cognitive, and affective factors could all influence the process of deliberation and reflection which resulted in the children (1) retaining their prior ideas, or (2) modifying the teacher's science to fit existing ideas, or (3) modifying and changing their existing ideas.

This process of deliberation and reflection was one in which the children showed impressive reasoning abilities and intelligence as they attempted to construct personal meanings for the teacher's science. For example, on November 26th, Mrs. L told the children that there was 'nothing' between air molecules, and although they found this idea to be both hard to believe and understand, they nevertheless attempted to construct personal meaning. Christa commented:

> C: In space, [the teacher] said there was nothing. And people go, 'What's nothing?'. Normally you say there is nothing between my thumb and my finger, but there is really air. And she is saying, nothing, like in no air, no nothing. And people are saying, 'What's nothing?', because we kept [thinking], 'Nothing is air'.

In this quotation, Christa began by relating the word nothing to the perception of nothing with which she was already familiar. She implied that the idea of nothingness was difficult to comprehend especially because the teacher's explanation appeared to conflict with expressions found in everyday communication. She then reasoned

> C: I think there is at least a touch of air, like oxygen, like maybe not oxygen, but a touch of air in space. Maybe not a whole lot, but there is probably some.

Clearly, Christa did not entirely accept the teacher's explanation of nothingness between air molecules, and nothingness in space, but instead she modified the teacher's science to render it compatible with her own ideas. This outcome was influenced by (a) her prior knowledge, (b) the links she generated between this knowledge and the teacher's science, and, (c) her intellectual ability. Additionally, the words and illustrations which the teacher used to present the idea of 'nothing between molecules' also influenced the meaning Christa constructed. Finally, such implicit factors as Christa's willingness to consider new ideas, to assume responsibility for her own learning, to question the believability of the science, and to accept the question of nothingness as being worthwhile underlay her deliberations and eventual explanation.

The existence of a constructed meaning, however, did not assure that the children were committed to these constructed meanings. Instead, the children's meanings seemed to swirl about, sometimes appearing to be held tightly, or simply recalled and repeated, or abandoned and then returned to, or only held by the most tentative bonds. These observations, and the struggle for personal understanding implied within them, suggest that for the children to subsume their constructed meanings or adopt these meanings as a scheme of their own expression, something more than identifying the new fact, making links with the familiar, and 'translating' and constructing these meanings had to occur.

4. Towards Adopting New Expressions

The children in this study frequently made observations and offered explanations for the teacher's science and this implied that they were constructing meanings of the teacher's science. It seemed, however, that the children were also faced with the decision as to whether they would make the final move to adopt these constructed meanings into their personal system of beliefs.

Schutz (1971) maintains that

> Only after having thus collected a certain knowledge of the interpretive function of the new cultural pattern may the stranger start to adopt it as the scheme of his [or her] own expression. The difference between the two steps . . . is the difference between the passive understanding of a language and its active mastering as a means for realizing one's own acts and thoughts. (p. 100)

Osborne and Wittrock (1983, 1985) seem close to Schutz's (1971) idea of 'active mastering' when they discuss the process of evaluating a constructed meaning, and the possibility that this meaning may be subsumed into memory store. They claim:

> If the constructed meaning makes sense in terms of its evaluation with other aspects of memory store then it may be incorporated into memory, influencing and possibly altering the memory store itself in the process. The greater the number of links generated to other aspects of memory store, and the greater the number of these links that reaffirm a useful constructed meaning has been made, the more likely the idea will be remembered and make sense to the learner. (Osborne, & Wittrock, 1985, p. 66)

Although Schutz (1971), and Osborne and Wittrock (1983, 1985) seem to recognize the process of adopting new schemes of expression, or subsuming constructed meanings, they do not claim that adoption or subsumption is an inevitable outcome of the children's struggle for understanding. Instead, Osborne and Wittrock (1983) discuss how some children may only construct minimal links between the teacher's science and what they already know, and that these links may tend to fade from memory with time. Schutz (1971) refers to the stranger "oscillating between remoteness and intimacy" (p. 103), experiencing "hesitation and uncertainty" (p. 103), and offers that the stranger's adoption of a new culture is a continuous process of inquiry that only succeeds when the new culture becomes "a matter of course, an unquestionable way of life, a shelter, and a protection" (p. 105).

Children's ability to construct meaning from the teacher's science should not imply that the children have adopted or subsumed these meanings. Some researchers observe that a child's explanation might simply be an echoing of the teacher's science, and not an explanation that they personally understand (Barnes, 1976; Biddulph, 1982b; Pope, 1982; West, & Fensham, 1974). Pope (1982) suggests that sometimes children's explanations represent a more passive repeating than an active mastering of the teacher's science.

> The teacher's science can be incorporated into a person's system of constructs, but it may remain fragmented, not connected in any meaningful way with the person's more crucial constructs. There would be no personal commitment to this compartmentalized view of the world. (p. 9)

How can we judge if a child has adopted or subsumed a constructed meaning, or whether the child is offering an explanation that is simply one of the many ideas he or she might consider during a struggle for personal understanding? How can we know if children have adopted the explanation, or if their explanation is simply an aspect of the teacher's science they have recalled or repeated but have not attempted to integrate into their existing ideas in a meaningful way?

Wittrock (1977) suggests that "learning with understanding is the process of transferring previous experience to new events and problems" (p. 177). White (1979) seems close to Wittrock's (1977) idea of learning with understanding when he describes the idea of mastery. In mastery, "understanding comes with integration of acquired skills and knowledge into meaningful wholes so that each element is not stored in memory in isolation but is linked to others, the recall of one cueing the recall of others" (White, 1979, p. 7). If learning with understanding and mastery are close to Osborne and Wittrock's (1985) idea of subsumption, and Schutz's (1971) idea of adoption, then one way to assess whether a child has subsumed or adopted a constructed meaning would be to ask the child questions which would require the child to apply this constructed meaning to a novel situation. In this way, perhaps as assessment could be made regarding whether the child has meaningfully learned the teacher's science, or whether the science has been learned by rote (Novak, 1985). In this study, however, the summary quiz that each child wrote did not require the children to apply the teacher's science to novel situations, and therefore it was difficult to judge if the children had adopted or subsumed the answers and explanations they offered.

Perhaps the format of this study, and the insight this format allows into the ongoing evolution of ideas during the course of a science unit, can offer some insight into what might be important to the issue of adoption or subsumption. During the study, the children frequently admitted that they wondered about the teacher's science, that they had doubts about the teacher's science, or that they did not believe the teacher's science. These comments suggest that at times the children lacked confidence in the teacher's science, and perhaps lacked confidence in the meanings they constructed of the teacher's science. The frequency and thoughtfulness of these comments implied that the children were in the process of coming to a personal understanding of the teacher's science. Simply, their own perceptions of their constructed meanings implied that they had not yet reached a point where they had subsumed or adopted all the meanings they offered as they attempted to explain the teacher's science.

For example, on November 17th, Gordon offered a short explanation about how ears could hear, and his explanation included a reference to the importance of a vibrating ear drum. Then, several lessons later he admitted:

> G: I still wonder how your ear all works. And [how sound] hits the ear drum and all the bones vibrate and [how sound goes] to the cochlea. And especially the cochlea thing and how it helps you stand up. That's something I really puzzle about.

This example reveals that although Gordon was able to offer a brief explanation of the process of hearing, he still wondered about this process. This implies that in spite of the observations he made, the links he generated, and the meanings he constructed, Gordon might not have understood his explanation, or maybe he was unsure or did not believe aspects of the teacher's explanation, or maybe he recognized there was much more to know. This might suggest that something more than linking together ideas or being able to recall information had to take place during the construction of personal meanings before Gordon would feel confident about his constructed meaning.

Driver and Bell (1986) have hypothesized that what might be key to constructing meanings and subsuming those meanings, could be the child's belief in those meanings. They have observed that "although students may successfully construct an intended meaning, they may be reluctant to accept or believe it" (Driver, & Bell, 1986, p. 451). Further, they argue that "learning involves not only constructing the intended ideas but also accepting them. Difficulties in learning science may arise at either the constructing or acceptance stage" (Driver, & Bell, 1986, p. 452).

Shapiro (1987) commented on the issue of believing in her classroom study about children progressing through a science unit on Light. She observed that one child "was able to give the correct response on the survey and in [the] interview, but she [did] not appear to believe the idea completely" (Shapiro, 1987, p. 176). On another occasion Shapiro (1987) commented that "it was clear that [the child] did not 'really believe' that the world functions in the ways that [the teacher] suggested" (p. 383).

This issue of belief surfaced in the children's previous comments about constructing meanings. For example, Victoria found it difficult to believe that vibrations could travel through narrow, skinny string. Christa had a hard time believing that sound travels faster through solids than air. Victoria's and Christa's comments about belief establish that as children construct meanings of the teacher's science, they are also making judgements about the believability of the teacher's science and perhaps experience some culture shock when they are presented with the teacher's science. Driver and Bell (1986) agree with this observation and add that this issue of belief also arises at the final acceptance stage, and this may imply that the subsumption and adoption of a constructed meaning, in part, also depends on whether the children believe that constructed meaning.

Although the issue of belief seems important in constructing and accepting meanings, it does not appear from the children's comments that belief could be separated from other comments they made about understanding and wondering. For example, if children wondered about some aspect of the teacher's science, it might mean that they had difficulty understanding the concept because they did not believe aspects of the teacher;s science. Perhaps by examining the children's comments about believing, wondering, and understanding this final step of subsumption or adoption can be illuminated. The children's comments about these issues are summarized in Table 9.

a) Children's Comments About Believing

The children made frequent statements which suggested that they were not entirely confident about their understanding of the teacher's science. Sometimes they would comment that they simply found it hard to believe the teacher's science, and on other occasions they would talk about how they wondered or puzzled about the science. These comments, and the questions the children possessed at the end of the science lesson, provided a "valuable guide to their perception of their world" (Symington, Biddulph, Happs, & Osborne, 1982, p. 1), and revealed that some children had constructed meanings about which they were not entirely confident.

On November 13th, Bob stated that although he knew that molecules were involved in the Slinky and marble demonstrations, he found it hard to believe in the existence of something he could not directly observe.

> B: If you could really see molecules, or something, you would believe it. But, you are just using examples with different objects.

This reliance on first-hand observation again surfaced when Bob

TABLE 9

Children's Comments About Believing, Wondering, and Understanding

A. Children are More Likely to Believe the Science if:

1. They can directly observe the science concept.
   e.g., believe molecules if you could really see them
2. They can directly observe the outcome associated with the phenomenon. e.g., waves in water mean molecules are vibrating
3. They have correctly anticipated the outcome of the activity or demonstration.
4. They can try the activity, make their own observations, and experience a successful outcome.
5. The science concept seems plausible.
6. The science is presented by an authority figure.
   e.g., the teacher demonstrates the activity

B. Believing - Wondering - Understanding

1. More likely to believe if they can directly observe the science concept and understand the concept.
   e.g., must see waves in water and understand underlying concept
2. Children can believe the science, but still wonder about the science and not understand the science. e.g., amplification of the hurdy gurdy.
3. Children can understand the science, but not believe the science. e.g., Gordon and acoustic tiles
4. Children can not believe, not understand, and still wonder.
   e.g., Victoria and acoustic tile
5. Children can find the science to be difficult to believe, difficult to understand, and still wonder about the science
   e.g., Samantha and acoustic tile

commented that initially he did not entirely believe that tuning forks could make splashes in a pan of water. But, the opportunity to try the activity for himself convinced him to really believe that tuning forks could make splashes.

Samantha also commented about believing during the November 10th lesson. She claimed she found the entire lesson to be believable because

S: . . . there wasn't really anything that we didn't see.

This comment suggests that the opportunity to observe activities directly was important to Samantha's willingness to believe, and perhaps, her ability to understand. It is interesting to note, however, that some of the concepts that Samantha claimed to see and to believe were not directly observable. Instead, Samantha observed the outcomes associated with vibration and these outcomes seemed sufficient to cause her to believe. She did add, however, that her decision about whether to believe a concept was based on her ability to understand the activity and her opportunity to observe the activity.

> S: I'm not very sure if it is true if I don't see it happen. [But], I thought that wasn't true when [the teacher] put the [tuning fork] in the [water because] I didn't get that. So, if I didn't get that, I might not believe that.

During a later interview, Samantha added that sometimes she believes a concept simply because of her opportunity to observe a teacher demonstration.

> S: As I always say, it is easier when you do [the activity] for yourself because you see the things that are happening, and you can try it yourself. . . . But, sometimes when [the teacher] shows it to us, I believe her.

On November 12th, Gordon stated that he did not believe the numbers on the tuning forks which indicated the number of times they vibrated in one second because the numbers simply seemed too large. He added, however, that he would believe the numbers if

> G: . . . you could show [a tuning fork] in slow motion and I [could] count the times, and see if I could count one second.

Similarly, on November 13th he had doubts that the demonstration involving the line of girls was an analogy for molecules even though he had previously offered this explanation. He felt, however, that his doubts could be erased if

> G: . . . you could really see [the molecules]. I would believe that then. But you can't. So, I don't know.

These quotations reveal that despite the implied authority of the teacher's information, Gordon was not willing to believe information which seemed counterintuitive or abstract, until he could actually prove to himself by direct observation that it was indeed true. He concluded his interview by admitting that he still wondered about numbers on tuning forks. In another interview, Gordon summarized that if he could directly observe the concept, had the opportunity to try the activity, and reached a successful outcome, then he believed the concept.

After the lesson ~~on November~~ 17th, Christa described how ears could hear sounds, but then she added that she found it hard to believe that such a complicated process could happen so quickly. In another lesson she found it hard to believe that everything was composed of matter. Perhaps Christa's comments about believing suggest that she found it difficult to believe information which defied her imagination, seemed amazing, or could not be observed directly.

In comparison to the other children, Victoria was more likely to comment that she believed everything about the science lesson, and that this belief was based on the fact that the teacher had presented the information. However, Victoria was able to express some doubt about the teacher's science by admitting that she wondered or puzzled about it, or that she found the teacher's science difficult to understand.

> V: I wonder about the bumps on the [textured] wall and the [acoustic] ceiling [tiles].
>
> V: . . . molecules, I'm still very puzzled about molecules.

In summary, it seemed that the children were more likely to believe the teacher's science if (a) they experienced personal success while doing the activity, or (b) they directly observed the science concept, or (c) they correctly anticipated the activity outcome, or (d) the concept was demonstrated by the teacher, or (e) they felt confident in their personal understanding of the teacher's science, or (f) they directly participated in the activity, or (g) they found the teacher's science to be plausible. Many of these factors seemed to revolve around the children's opportunity to participate in hands-on activities. Simply, if the children could anticipate the activity outcome, directly participate in the activity, directly observe the science phenomenon, and arrive at a successful conclusion to the activity, then they were more likely to believe the meanings they constructed, to feel confident about these meanings, and perhaps to adopt or subsume these meanings.

In this study, the children participated in many hands-on activities, but they also viewed three films which were intended to introduce or expand upon some Sound concepts, and the comments they made about believing films seem particularly revealing.

b) Children's Comments About Believing Films

Bob commented that although he did not doubt the science content of films, he really believed and understood the science concepts if he had the opportunity to try it for himself.

> B: I understand more when I try it out because after you'll believe it more or something. Well, maybe you can believe it on a film, but you can really believe it if you tried it.

Gordon seemed to have less confidence in the believability of films and explained that seeing wasn't always believing.

> G: [On a film], I wouldn't really believe it. You know it is hard to believe that [beakers] . . . with lower [amounts of water] will make high sounds. And I wouldn't believe that if I saw it on a film.

> G: Seeing isn't always believing. That's how it is to me because I don't really believe that Luke Skywalker when they were having sword fighting, I didn't believe that they would chop his arm off and then he would fall and he would catch the TV antennae. I don't really believe that part.

Clearly, Gordon's movie viewing outside of the classroom, and his knowledge of the use of special effects, influenced him to doubt the believability of the science films he watched in class.

Samantha maintained that although the teacher's jar and bell demonstration was not entirely successful, she still preferred the demonstration because on a film

> S: I can't really see it. . . . It might be anything because movies and filmstrips can get [any results].

Similarly, Christa also preferred the teacher's demonstrations because it gave her a more realistic impression of science.

> C: . . . because in the films they always get things to work. They always make it look like it works and say, 'Hey, this tin can telephone works. To make it you need this, this, and this.' But, it doesn't always work in real life.
>
> C: They get everything to work on a film. Some things in life just don't work.

Victoria thought hands-on activities were more believable than films because a film reduced her to the role of just watching the science.

> V: It's better to do it with things because again, you're doing an experiment and you can figure it out. With [a film] it is just like they are doing your work [and] you're just watching.

In summary, the children's comments about films make clear that some children recognized that a film could rely on special effects, or could contain orchestrated, unrealistically successful science demonstrations which could not be duplicated in real life. Further, films reduced the children to just watching the science, and the children seemed to recognize that believing required more than just watching. Once again this points to the important role hands-on activities seemed to play in the children's willingness to believe the teacher's science, and to feel confident about the meanings they construct.

c) Children's Comments About Wondering

The children's comments about believing reveal that believing is not some isolated aspect of the children's process of deliberation, but rather, believing is intertwined with understanding and wondering. Therefore, perhaps the construction and acceptance of personal meanings are not only influenced by the children's belief, but also by their understanding and confidence in the teacher's science.

On December 8th, the teacher demonstrated that the sound from a hurdy gurdy could be amplified if the hurdy gurdy was placed against a wall or desk. Bob, Gordon, Samantha, and Christa all maintained that they believed this demonstration because they had heard the louder sound. However, they all added that they wondered about this demonstration because they could not understand the reason behind the amplification. In this example, it seems that the children's opportunity to directly observe the amplification influenced them to believe, but still left them with a sense that they did not completely understand the teacher's science. This implies that belief can precede understanding and that if children claim they believe some aspect of the teacher's science, it does not necessarily mean that they understand the teacher's science or feel confident in the meanings they construct.

> B: . . . like a desk is flat and smooth and hard, and it makes [the hurdy gurdy] have a louder sound.
>
> B: I believed about the desk [making the hurdy gurdy have a louder sound].
>
> B: [I wonder] about the desk.

On December 7th, the teacher explained to the children that acoustic ceiling tile, and the wall's textured surface, were capable of absorbing sound. However, although Mrs. L drew a diagram on the board to assist her explanation, the children did not have the opportunity to compare the level of sound in their classroom to the level of sound in a room which lacked these acoustic materials. Gordon concluded that although he understood the teacher's explanation, he found it difficult to believe. Victoria admitted that she did not understand the teacher's explanation and therefore did not believe the teacher's explanation, and still wondered about this aspect of the lesson. Samantha was able to recall and repeat the teacher's explanation, but then added that she found this concept to be difficult to believe, hard to understand, and something about which she still wondered.

> S: But, it is hard to believe [the teacher's explanation]. [It is hard to believe that] a big sound [can go] into the little holes.

Christa was also able to recall and repeat the teacher's explanation, but then she added

> C: How come hard [surfaces] don't absorb sound?

These comments about wondering, believing, and understanding seem to support the idea that believing is in part dependent on the children's opportunity to observe directly the outcome of a teacher demonstration or observe directly the outcome of a hands-on activity. Believing an observation, however, did not necessarily mean that the children understood the teacher's science or felt confident in the explanations they offered about the teacher's science. Instead, perhaps a combination of believing, personal comprehension, and confidence were all required before the children felt satisfied that they had come to a personal understanding of the teacher's science.

d) Summary Discussion

The children's comments over the course of this study revealed that a combination of situational, cognitive, and affective factors influenced the meanings the children constructed of the teacher's science. In class, the teacher's choice of words, materials, or her method of presentation could affect the children's constructed meanings. The knowledge the children brought to the class and their ability to make links and perceive connections also shaped the content of the constructed meanings. The children's motivation, commitment, willingness to take responsibility for their own learning, and willingness to encounter new ideas also played a role in constructing meaning.

These situational, cognitive, and affective factors influenced the process in which each child judged, evaluated, and deliberated over the teacher's science. During this deliberation the children argued with themselves about whether they could believe the teacher's science, whether they could comprehend the teacher's science, whether they had confidence in the teacher's science, whether the teacher's science seemed plausible, and whether the teacher's science fit what they already knew. This process of deliberation resulted in the children constructing meanings for the teacher's science which could be resistant to change, or could be fleeting in nature, or could be gradually extended and modified.

It did not seem clear, however, if the children had subsumed or adopted their constructed meanings. This was, in part, due to the children's remarks that it was possible to believe their constructed meanings but not understand these meanings, and equally, that it was possible to understand their constructed meanings but not believe these meanings. These remarks emphasized that the construction and adoption of meanings was not solely dependent on the ability to perform some cognitive manipulations of the teacher's science, but was also permeated by the children's imagination, intuition, faith, and personal convictions.

Furthermore, it was difficult to assess just what is meant by subsumption and adoption. Osborne and Wittrock (1985) maintain that subsumption has occurred when the new meaning is "incorporated into memory, influencing and possibly altering the memory store itself in the process" (p. 66). This might imply that when the children are willing to incorporate their constructed meanings into their prior ideas, even if this incorporation risks altering their prior ideas, then subsumption has occurred. Schutz (1971) offers that adoption has occurred when the new culture becomes "a matter of course, an unquestionable way of life, a shelter, and a protection" (p. 105). This implies that when the children feel secure about their constructed meanings, and perhaps even use these meanings to interpret yet another new culture, then maybe we can assume that adoption has occurred.

In order to come to any conclusions regarding the children's adoption or subsumption of their personal meanings, perhaps we could observe the children as they approached another new, and yet related, unit of science. Would their prior ideas about this new unit of science contain references to their personal meanings of Sound, or would the children offer ideas garnered from outside the science classroom? Would the children generate links between their personal meanings of Sound and this new unit, or would they link the new unit to other ideas and experiences? Finally, would the children reject some of the teacher's science in the new unit because their personal meanings of the Sound unit appeared more sensible and satisfactory, or would the children reject aspects of the teacher's science because of a combination of other situational, cognitive, and affective factors?

This discussion about the difficulty of judging whether subsumption or adoption has occurred contains some implications for the teaching and evaluation of science in elementary classrooms. Additionally, the children's comments about making observations, perceiving the purpose of the lesson or task, generating links, constructing meanings, believing, and wondering all suggest that although the children's struggle for personal understanding is both personal and unique, there are implications for classroom teaching which can potentially assist and enhance the construction and adoption of personal meanings.

Chapter Eight

Conclusions and Implications

This chapter presents conclusions and implications which emerged from the examination of the teacher's presentation of the Sound unit, and the exploration of the children's experience of the teacher's science. The chapter begins with conclusions and implications which support and challenge ideas, models, and methodologies associated with alternative framework research. Next, implications for presenting science and Sound which arose from the children's and Mrs. L's comments are combined with ideas offered by other researchers to develop a teaching model which might be compatible with the view of learning and teaching presented in previous chapters. Finally, implications for pre-service teacher education are offered, and the chapter concludes with ideas for future research.

A. Conclusions and Implications for Alternative Framework Research

The teacher's comments about presenting the Sound unit, the children's conversations about participating in the unit, and my experiences of observing and interviewing both the teacher and the children, provided ideas which could potentially interest researchers involved in alternative framework research. Specifically, these ideas could inform questions about how children construct personal understanding, could provide some implications for the Generative Learning Model, and could offer some insight into research methodologies which have been used in alternative framework research.

1. Constructing Personal Understanding Through Conversation

At the conclusion of the Sound unit, I reflected on the children's words and the teacher's comments, and wondered how to summarize their complex views of learning, teaching, and collaboration. It seemed to me that similarities between the assumptions underlying a situational interpretive study like this study, and the assumptions underlying the words of the teacher and children, provided a metaphor for how children construct personal understanding.

Situational interpretive studies are based on the idea that each person brings his or her own expertise, knowledge, and viewpoints to the research situation. Another assumption is that as people participate in a situation, they interpret the same event in different ways and give personal meanings to its various aspects (Aoki, 1984). The researcher, therefore, must focus on the multiple viewpoints that people bring to and use to interpret a situation. A situational interpretive study such as a collaborative study, then, is based on "intersubjective dialogue" with people in the situation (Werner, 1984).

In this study, the assumptions and methods of situational interpretive studies seemed to act as a metaphor for the children's experience of constructing personal understanding. Each child brought his or her viewpoints, skills, and prior knowledge to the Sound unit. As they participated in the Sound unit, each child interpreted the teacher's science in an individual way and gave personal meaning to each aspect of the situation. The result was that as I recorded the children's prior knowledge, and interviewed them throughout the unit about the unique interpretations they constructed of the teacher's science, it appeared that the observations they made, the links they generated, and the meanings they constructed were the outcomes of a personal dialogue with themselves, and a public dialogue with other participants, both of which occurred as the children were immersed in the situational factors of the classroom.

The metaphor that constructing understanding is like a dialogue or conversation can potentially explain many of the children's comments, and Mrs. L's and my subsequent discussions of the complex, evolving, and subjective nature of the children's construction of meaning. First, dialogue is not a strict, objective, intellectual exercise, but rather always contains the personality, philosophy, and imagination of the participants. Like a stranger approaching a new culture, the children brought their history and their "thinking as usual" (Schutz, 1971) to the science classroom, and this knowledge and history was used to identify familiar aspects of the new culture and guide the process of deliberation which characterized the construction of meaning. Mrs. L and I discussed the children's construction of a variety of meanings for the science which was influenced by the children's prior knowledge and intellectual abilities. We suspected, however, that the children's personalities and philosophies also played a role in the construction of meaning, and this now seems compatible with the metaphor of dialogue, and SChutz's (1971) description of a stranger experiencing a process of social assimilation.

For example, if children construct a meaning of the teacher's science which is different from what the teacher intended, this could mean that (a) they have not understood the teacher's science, or (b) their prior ideas influenced them to construct an alternative meaning, or (c) they modified the teacher's science to support their existing ideas. Equally, alternative meanings of the teacher's science could mean that (a) the child was not attending to the teacher's science, or (b) the child did not believe the teacher's science, or (c) although the child was aware of the teacher's science, the child felt more security with the meanings he or she personally constructed. These possible reasons for children constructing alternative meanings of the teacher's science show that constructing meaning is more than an intellectual exercise involving the construction of links. Instead, constructing meaning is characterized by the children conversing with themselves and with each other while judging the believability, sensibility, and potential security of the teacher's science.

The idea of a dialogue can also be used to discuss Mrs. L's and my observation that at times we could anticipate how a certain child would approach and react to a lesson, and at other times we could be surprised by how the same child would approach another lesson. Some researchers who have explored how children approach learning have subsequently developed lists of learning or cognitive styles into which children can be categorized. Corno and Snow (1986) observe that

> We associate [cognitive or learning styles] with the overlap between individual differences in intellectual abilities and personality characteristics. This is consistent

> with Messick's (1972) definition of cognitive styles as 'information processing regularities that develop in congenial ways around underlying personality trends ' (p. 4). (Corno, & Snow, 1986, p. 617)

Corno and Snow (1986) then add that cognitive styles describe children's "typical propensity for a certain manner of work in given situations" (p. 617).

In this study, however, it seems that although the children's approach and reaction to the teacher's science was influenced by intellectual ability and personality characteristics, the teacher's presentation of the science lesson, and the children's prior experiences were also significant factors in determining how the children would approach and react to the teacher's science. This suggests that the construction of meaning, like a dialogue, is influenced by what the participants bring to the situation or conversation, is immersed in the situation in which the participants find themselves, and is permeated by the intellect, personalities, and philosophies of the participants. For example, during the Sound unit, Victoria sometimes approached the teacher's science in a probing, methodical, critical style, and on other occasions she seemed more likely to accept and repeat the teacher's science. It seemed that these apparently differing 'styles' were not only the result of cognitive and affective factors, but were also influenced by Victoria's (a) familiarity with aspects of the lesson, or her (b) perception of identical words, objects, and actions, or her (c) opportunity to work along or with other children, or (d) the richness of her prior experiences of sound. Therefore, although cognitive and affective factors do influence the construction of personal understanding, it must be added that the teacher's presentation of the science, and the children's prior knowledge are also important, and, perhaps this precludes categorizing the children into some consistent cognitive or learning style.

The idea of dialogue or conversation and Schutz's (1971) description of a stranger can also be used to describe the process of struggling towards personal understanding. It appeared that when the children were first exposed to some aspect of the teacher's science, they participated in an internal, private dialogue in which they tended to seek out familiar elements in the teacher's science, and then relate these elements to information already stored in memory. This is similar to Schutz's (1971) idea that the stranger may begin to interpret a new culture in terms of his or her home surroundings. The process of relating the teacher's science to what they already knew seemed at times to have a creative, imaginative element, and could be influenced by an external dialogue with other classroom participants, and by the teacher's presentation of the science. The links the children made between the teacher's science and what they already knew were tentative and displayed differing degrees of meaningfulness of thought. Schutz (1971) describes this tentativeness as being characteristic of the stranger who oscillates between remoteness and intimacy, and may be "unwilling or unable to substitute the new cultural pattern for that of the home group" (p. 104). This oscillation may, in part, be indicative of the culture shock the children may feel when presented with the teacher's science. Wittrock (1986) interprets the tentative nature of children's comments to be an indication of the meaningfulness of the links the children have generated.

> Both learning with understanding and factual or other learning that need not lead to understanding involve the learner generation of relations. However, the meaningful nature of the relations differs because of the way the information relates to other information, to the learner's experience, and the learner's organized knowledge. (p. 306)

Perhaps the meaningful nature of the links was influenced by such factors as the richness of the children's prior experiences, their intellect and personalities, and those factors which the children identified as influencing their willingness to believe the teacher's science.

As the children formed links between the teacher's science and what they already knew, they were continually making judgements and conversing with themselves about these links, and what the links potentially implied about their existing ideas and the teacher's science. These judgements could result in the retention, modification, and extension of existing ideas, or the modification of the teacher's science to support existing ideas, or even what appeared to be a sudden substitution of existing ideas with the teacher's science such as that experienced by Gordon when he heard the janitor vacuuming in the hallway. Again, the children's judgements seemed to be influenced by a combination of cognitive and affective factors, in addition to their prior experiences and the teacher's presentation of the science.

The links the children made, and the personal and public dialogue that existed between the children and the teacher's presentation of the science, led to the formulation of personal meanings which could be at variance with what the teacher intended, and could contain a combination of ideas bound by meaningful links, and ideas which seemed to possess only a tenuous, doubtful association with the children's personal meanings. It was difficult to assess if and what personal meanings were subsumed or adopted by the children, or whether only those ideas bound by meaningful, quality links potentially stood to be subsumed. Schutz (1971) proposes that the stranger may remain in a continuous process of inquiry; perhaps the stranger's conversation with the new culture does not end. Regardless, this process of struggling towards a personal understanding did establish that the children actively tried to understand the teacher's science, that their ideas evolved and changed throughout the science unit, that their alternative ideas were intelligent and justifiable, and that the children were willing to persist towards forming a more personally coherent view of the world.

This picture of how the children constructed meaning suggests that the construction of meaning is not some mechanical, lock-step, analytical pursuit, but rather bears resemblance to a dialogue in which the children approach new ideas, reason with themselves, converse with other children, and are influenced by the classroom situation. This dialogue is influenced by the intellectual capabilities, personalities, and philosophies of the children, and perhaps this suggests that any hypotheses regarding the nature, content, and construction of children's meanings should include a recognition that children bring much more to the science classroom than prior ideas about the science topic.

Finally, this idea that constructing meaning is like a dialogue seems to mirror and describe our stance in the world. The children's act of constructing meaning involved participating in the science class and searching for some personal meaning of the teacher's science through conversations with themselves and with others. These actions also underlie our position in the world in that we are not isolated entities, but rather we define the world through our interconnection and relationship with it. We do not stand alone but are constantly reaching out to the world in our search for personal meaning. Maybe when the children talked about their participation in science, and how they constructed personal meanings of the teacher's science, they were also describing our essential participation or conversation with the world and how through this continual conversation we discover and give meaning to our world and our Selves.

2. Generative Learning Model

Osborne and Wittrock (1985) admit that "any model to do with human learning is an oversimplification of reality. The generative learning model is no exception" (p. 66). The purpose of these models, however, is to provide a focus for discussion and thought, and to provide a representation of reality which can then be used for the less strenuous purposes of comparison and critique. In this study, the children's comments at times seemed to support some aspects of the Generative Learning Model, and at other times challenged some aspects of this model. These issues are discussed in the following paragraphs.

One criticism concerned the vocabulary of the Generative

Learning Model. Chapter Seven began with the assertion that the terminology of the Generative Learning Model seemed mechanical and did not appear to portray the children's human experience of science. Perhaps the children's comments about belief, and my discussion about how the construction of meaning might resemble a dialogue or conversation supports this initial assertion. Additionally, the Generative Learning Model contains the term cognitive structure and White and Tisher (1986) note that "in science education, cognitive structure is commonly defined as the representation of relations between elements of memory" (p. 883). Perhaps this term implies a static model of relationships, and maybe learning models should strive to incorporate terminology which can portray the dynamic, evolving relationships which emerged during this study.

Another criticism of the Generative Learning Model could regard the fragmented view of children implied in discussions about the construction of meaning. Pope and Keen (1981) argue that perhaps by taking a more holistic view of children and recognizing that affective factors integrate with cognitive factors in children's attempts to make sense of the teacher's science, greater attention can be focussed on the interdependence of factors which influence children's struggle for understanding. Certainly this interdependence emerged in this study and was described as being a natural part of conversation or dialogue, however, perhaps the sheer, complicated, weaving of factors will overwhelm efforts to identify and present practical implications suitable for classroom use. Osborne and Wittrock (1985) argue:

> While accepting the interdependence of factors such as selection, attention, and so on - and the importance of maintaining a holistic viewpoint - we consider that in teasing out aspects of learning, using the key postulates of the model, specific implications for teaching and learning can be isolated and focussed on. (p. 70)

Therefore, although the interdependence of factors reflects the reality of the children's struggle for understanding and should be presented to teachers interested in how children approach teacher's science, it may be necessary to draw cautious boundaries around some of these factors in order to indicate implications which would be useful within the existing structure and philosophy of schools.

In this study, the children's comments seem to support the Generative Learning Model's contention that children refer to their prior experiences and knowledge, and generate links which assist in constructing meanings of the teacher's science. Certainly, the children's many references to experiences at home and their ideas about Sound support this idea. However, perhaps the Generative Learning Model could be expanded to include the idea that although the children do make links between the teacher's science and what they already know, the act of making these links may involve a creative, imaginative element.

The Generative Learning Model accounts for the children possessing ideas which are uninfluenced, or influenced in unanticipated ways by classroom experiences, by emphasizing the role of existing ideas on the children's science ideas, and the role of the links which are generated in a unique way to unanticipated aspects of memory store. Perhaps the role the presentation of the science lesson, and the content of those lessons play on the children's ideas could be added to this list of factors which influence children's ideas. For example, it seemed that the children could possess uninfluenced ideas or ideas influenced in unanticipated ways because the children did not believe an aspect of the teacher's science that was presented in a film. Although this does not exclude the influence of existing ideas on determining the children's ideas about science, it perhaps does draw attention to the importance of including classroom factors in any discussion about children's ideas in school situations.

3. Research Methodologies in Alternative Framework Research

Researchers have presented critiques of methodologies which have been used in the area of alternative framework research (Posner, & Gertzog, 1982; Sutton, 1980). The influence of collaborative methodologies on this study was presented in Chapter Five. There were, however, other ideas which grew out of the children's comments about Sound that may contain implications for lists of children's alternative ideas, and for methodologies involving interviewing children.

Driver and Easley (1978) have noted that the compilation of lists of children's ideas does "not yield interpretive power" (p. 69). They emphasize that we must understand the reasons behind children's ideas before "progress can be made in instructional terms" (p. 68). Osborne, Biddulph, Freyberg, and Symington (1982) add that "research which simply points out mismatches between the teaching and learning of science is likely to . . . reduce the science component of the curriculum actually provided in the classroom" (p. 4). Further, Driver and Erickson (1983) have suggested that research techniques used to investigate and discover children's ideas may influence the nature and content of those ideas.

> We suggest that student's responses may differ significantly depending on whether they are investigated using a technique which is conceptually framed [e.g., word association, concept mapping] or one based on an actual event or phenomenon: the former eliciting propositional knowledge and the latter what we call knowledge-in-action. (p. 43)

In this study, it was obvious that the children had many ideas about sound which could be called 'knowledge-in-action' and could have been presented in the form of a list of alternative ideas. However, what seemed clear from my conversations with the children was that these ideas were open to many interpretations. For example, it did not seem clear if these alternative ideas were (a) ideas that the children believed, or (b) ideas that the children just recalled and repeated, or (c) ideas which the children were just considering during the process of understanding, or (d) ideas the children spontaneously invented to please me or to avoid embarrassment. Simply, the ideas which could have been listed and referred to as Children's Alternative Ideas About Sound, would not have been an accurate reflection of the children's personal understanding of sound. Therefore, although lists of ideas may be interesting to read, the lists should not be presented as containing ideas which children have subsumed or adopted, the lists should not be used to indicate the failure of current teaching practices, and the lists should not be used to found a new set of curriculum materials intended to 'correct' these ideas.

In the study it seemed that the interview situation was capable of causing the children to forget details of the lessons, or to provide answers about which they were unsure. Driver, Guesne, and Tiberghien (1985) comment that:

> One of the problems involved in investigating children's ideas is devising ways of probing thinking which enable us to sort out the status of the responses we obtain; to distinguish between those ideas which play a significant part in the thinking of an individual or a group and those which are generated in an ad hoc way in response to the social pressure to produce an answer in an interview or test situation. (p. 196)

As the study progressed, however, it seemed that the children were more likely to express openly their uncertainty about the explanations they offered, were more likely to admit to strategic inattention, and were more likely to decline to answer some questions. Perhaps this change was due in part to the length of the study and the time this allowed for building a relationship of trust with the children, and the children's gradual realization that all answers were acceptable. This might suggest that studies which are carried out over a length of time, and are conducted in an atmosphere of trust and openness may provide the environment in which the status of children's responses can be assessed.

Finally, the duration of the study, and the opportunity the children had to respond to parts of the teacher's science which were part of their classroom science unit, combined to create a picture of children in science which emphasized the range of ideas they possessed, and the intelligence of these ideas. Perhaps alternative framework methodologies which involve removing children from the classroom context and asking the children to respond to situations or questions generated in isolation by the researcher, work against arriving at an appreciation of the intelligence of the network of ideas which lie behind the children's answers, and which come from the children's participation in science class.

B. Implications for Presenting Science and Sound to Children

Any implications for presenting science and sound to children should be consistent with the view of constructing personal understanding which emerged from the children's comments. Also, implications should be sympathetic to the teacher's experience of working within a school system, and the teacher's concerns about time restrictions, lack of equipment, limited pre-service preparation, discipline, available resources, curriculum responsibilities, and provincial and system-wide formal evaluations. Further, perhaps this concern for implications which are sensitive to the children's experience of learning, and are sensitive to the teacher's experience of teaching in the existing school system, reveals the potential for conflict between a constructivist view of learning and the philosophy and structure of the existing school system. Biddulph (1982b) identifies one conflict which may exist between a constructivist view of learning and current teaching models.

> The common teaching model used may well result in some problems as far as children's learning in science is concerned. The communication system established by teachers using this model carries embedded in it the notion that knowledge is something that is received from an authority rather than something that students construct for themselves. (p. 28)

Barnes (1976) adds "there is an implicit conflict between the teacher's responsibility for control and his [or her] responsibility for learning: the one treats pupils as receivers and the other treats them as makers" (p. 176). Therefore, perhaps any implications suggested must strive to strike a balance between the constructivist view of learning and the structure of the existing school system until such time that change can occur to current conceptions of school in society. White (1983) offers:

> Schools have had such a long run in their present form . . . that we tend to assume that they are permanent, stable, easily able to resist attempts to change them. They are, however, instruments of society, and once a view builds up that they are not meeting the needs of society they will be forced to change. (p. 3)

In this study, the unanticipated ideas which the children possessed, and the children's reasons for these ideas, gave Mrs. L and me the idea that the teacher stood on the periphery of the children's struggle for personal understanding. To an extent, this was correct because the links that the children made between existing ideas in memory store and incoming sensory information were something only they could make. Osborne and Wittrock (1985) have made similar observations and argue that "[uninfluenced ideas] re-emphasize the complete lack of direct control a teacher has in ensuring that specific constructions occur and in ensuring existing ideas are influenced in hoped for ways" (p. 69). However, the children's comments about the lessons' purpose, making observations, and what influenced their belief, in addition to my discussion of the difficulty of assessing subsumption and adoption, reveal that the teacher can play a role in assisting the children to construct meanings which approach what the teacher intended, and can play a role in clarifying the assessment of subsumption.

But, it is inconsistent to include the teacher in collaboration with data, and yet to exclude her from providing and assessing implications derived from that data. Olson (1982a) warns that "if we adopt the idea that the role of the outsider is to offer the insider guidance, not orders, then we are led to consult the insider by the very nature of the guidance act itself" (p. 21). Therefore, Mrs. L participated in the formulation of the ideas presented in this chapter, and provided comments about them and the observations she made which influenced her. The following section describes how Mrs. L's ideas about student understanding were changed or modified as a result of participating in this study, and then the implications which emerged from her thoughts are blended with implications offered by other researchers to form some tentative ideas for a teaching model, for the role of the teacher within this model, and for potential questions about sound which might be contained in this model.

1. Teacher's Observations of Student Understanding

Mrs. L wrote that she had initially expected that the children would have understood more of the content of the Sound unit than what appeared in the interview transcripts.

> In regards to the science content of this unit, I suppose I thought the children would learn more than I can now see they do. The [interview] transcripts show that the [five children] already had some good prior ideas about sound, and experience with sound. The [Sound] unit seems to have added only a little real learning [where they felt they understood things], and in fact [the Sound unit] hasn't changed too many of their original notions.

Mrs. L summarized by saying that probably all the children in the class still found it difficult to understand such ideas as: (a) how sound is made, (b) how sound travels, (c) what makes high and low sound, (d) amplification, (e) vacuums, and (f) some of the vocabulary.

Mrs. L was also impressed with the unique, personal way in which the children approached the science activities, and the variety of ideas the children possessed at the end of the lesson.

> The transcripts impressively show what you have been saying about how children bring a unique approach to their learning, and that their interpretations of what they learned from doing the same activities varies astonishingly. I primarily think of how very different [Victoria's] interpretations were.
>
> [The children's] varied explanations for the same phenomenon were a revelation to me. I no longer will be sure of just what [the children] are in fact learning in science. What's impressive is that they came to such different notions after willingly carrying out the tasks in similar ways.

The children's creativity and the way in which they invented new uses for the science materials also impressed Mrs. L.

> [The children] not only had no trouble with the tasks, but the transcripts show that they all found it easy to come up with new and different uses for the materials given time.

The Sound unit also contained abstract concepts involving energy, molecules, sound waves, and the structure of matter. Mrs. L wrote:

> I thought [abstract ideas] were too difficult, now I know they are. I really have to admire the children for the way they earnestly considered all the new, [and abstract] ideas, and how they willingly made attempts to come up with explanations acceptable to themselves.
>
> The transcripts showed [the children] learned easy things - names of new objects, new physical skills such as using a tin can telephone effectively, ringing tuning forks, and vibrating sound sticks.

Mrs. L summarized by saying that there seemed to be many factors which influenced the children's personal understanding of the Sound unit, and among these factors were (a) the opportunity for hands-on experiences, (b) the time allowed for the activities, (c) the personalities of the children, (d) the children's motivation to learn, (e) the children's readiness to learn, and (f) the content of the science unit. She commented:

> Obviously when [the children] can do something, they think that they have found out something. Then, when you hear what they believe, it's something about a table being hollow. I think that [the children] feel they have moved on in their knowledge when they have done something.
>
> The children [learned] what they have tested and tried for themselves. They learn what they want to, and they don't learn what they don't want to. The question here is: What is the influence? Is it personality, or a lack of curiosity, or what do we even mean by [personality and curiosity]?
>
> I think [the children] learn something when they are ready to learn it. . . . Otherwise, they just have a memorized answer, and I think those fade very quickly. Some of the [children] were unable to answer my [review questions] at the end of the unit. I believed they understood earlier when the explanation was still ringing in their ears, but then [their explanation] was gone by [the end of the unit].

These comments, observations, and summary statements regarding how the teacher's ideas about student understanding were changed and modified as a result of this study naturally led to discussions about how teachers should approach the presentation of science in elementary classrooms. The tentative ideas which emerged from these discussions, and additional ideas offered by other researchers, are presented in the remainder of this section.

2. Current Ideas for Teaching Models

Many researchers have presented models and implications for teaching science which are sensitive to a constructivist view of learning (Barnes, 1976; Biddulph, & McMinn, 1983; Biddulph, & Osborne, 1983; Biddulph, Osborne, & Freyberg, 1983; Biddulph, & Roger, 1983; Champagne, Gunstone, & Klopfer, 1983; Driver, &

Bell, 1986; Driver, & Easley, 1978; Driver, Guesne, & Tiberghien, 1985; Harlen, & Osborne, 1985; Osborne, Biddulph, Freyberg, & Symington, 1982; Osborne, & Wittrock, 1983; Osborne, & Wittrock; 1985; Renner, 1982; Symington, Biddulph, Happs, & Osborne, 1982; White, 1979; Wittrock, 1986). The philosophy underlying these models and implications seems in part to be reminiscent of the *Elementary Science Study* curriculum materials. Symington, Biddulph, Happs, and Osborne (1982) maintain that:

> Teaching science in the primary school should help children to achieve more meaningful interaction with their world. Meaningfulness has two aspects, viz, being able to *do* things, and being able to made sense of the world. . . . *While we need to help younger children act on, observe, and attempt to understand their immediate world in their own way as they grow*, we also need to help them: (i) appreciate and be interested in a wider view of the world; and (ii) be interested in other people's explanations of the world and how such explanations have been obtained. (p. 3,4)

This philosophy, and mutations and interpretations of this philosophy, have been balanced against the observations researchers have made about children's classroom science experiences, and the ideas children possess about teacher's science. This has resulted in suggestions about children, teachers, and curriculum which include:

1. science lessons should be based on children's questions;
2. children should become more responsible learners;
3. teachers should facilitate children's construction of meaning;
4. teachers should help children relate new information to their existing ideas;
5. the content of current science curricula should be modified;
6. new forms of assessment should be developed;

7. teachers should explore children's prior ideas;
8. greater time should be allowed to science;
9. science tasks should be more open-ended;
10. children should be encouraged to share and exchange ideas;
11. and, children should be exposed to a variety of concrete experiences.

These suggestions are meant to put children at the center of the learning experience and to involve them in tasks which are concrete, relevant, and involve children in independently exploring their own questions about the science topic. Teachers assume the role of facilitator of the children's learning, helping children to relate the science to what they already know, questioning the children about their independent explorations, and providing an environment in which children may exchange and share in their discoveries.

This view of children and teachers can be found in the Learning in Science Project's [LISP] Alternative Teaching Strategy (Biddulph, & Roger, 1983), and in Harlen and Osborne's (1985) recommendations for a teaching model based on an exploration phase, investigation phase, and a reflection phase. Both of these models emphasize that the ideas children possess about the science topic should form the basis of science units in which children independently explore their own questions, and then report their findings to the rest of the class (Biddulph, & McMinn, 1983; Biddulph, & Osborne, 1982; Biddulph, & Roger, 1983; Harlen, & Osborne, 1985). Teachers who have tried teaching models based on children's independent exploration of questions, however, have commented that there are some problems with this model which include:

1. the difficulty of guiding children to select suitable, manageable questions'
2. a lack of appropriate resource materials;
3. the considerable amount of time required by the children to explore their questions;
4. the teacher's sense that there was a lack of clearly defined goals'
5. the teacher's sense of uncertainty about the direction of the science unit and what he or she was trying to achieve;
6. the difficulty children experienced trying to carry out scientific investigations;
7. the researcher's reservations about whether worthwhile learning was taking place;
8. the children's variable interest in the reports of others, especially if these reports were lengthy; and
9. the children's requests that sometimes they would like to be told the answers to some of their questions. (Adapted from Biddulph, & McMinn, 1983)

On the positive side, the teachers commented that:

1. the children were motivated and interested;
2. the children engaged in research outside the classroom;
3. the children seemed more in control; and
4. the children's intelligence and thoughtfulness were revealed to a greater extent than they would have been in a more traditional classroom setting. (Adapted from Biddulph, & McMinn, 1983)

Perhaps these pros and cons of a model based on children independently exploring their own questions imply that although children's questions can be a starting point for motivated, enthusiastic learning, this approach should be balanced with more teacher-directed approaches to teaching which could be modified to encourage children to generate a personal understanding of the teacher's science, and which could contain a structure and sense of purpose with which teachers might be more comfortable. In this way, a balanced approach would be sensitive to the variety of experience, knowledge, and personal preferences teachers bring to the classroom, and to the teacher's experience of working within the existing school system. This balanced approach to teaching is presented in the following section.

3. A Balanced Approach to Presenting Science

The balanced approach to the presentation of science is based on the idea that science units can be sympathetic to a constructivist view of learning, can incorporate student-generated questions, and yet can contain times of direct instruction, teacher demonstrations, film viewing, teacher-directed activities, and independent student exploration. An outline of this model is presented in Table 10, and this model is discussed in the following sections.

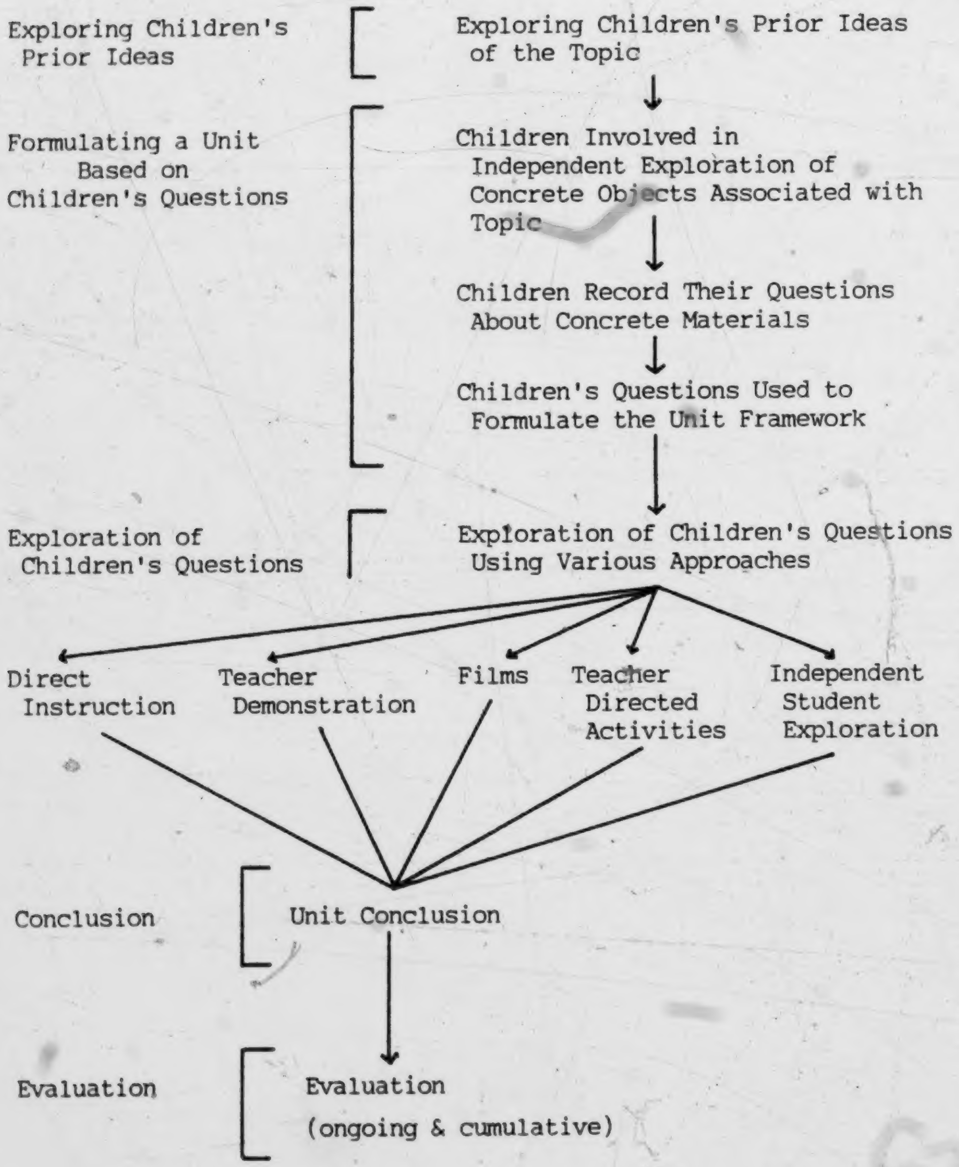
a) Exploring Children's Prior Ideas of the Topic

> There is now a growing group of educators who argue that, for the teaching/learning dialogue to be effective, it is important for the teacher to come to an understanding of the student's frameworks. What is relevant to the learner is of importance, and for education to be a joint venture between teacher and learner, it is essential that each has some awareness of the other's personal constructs. (Pope, 1982, p. 8)

In this study, the children's frequent references to their prior ideas, and the idea that understanding arises from the links the children make between the teacher's science and what they already know, suggests the importance of gaining knowledge of the

TABLE 10

Balanced Teaching Model


Exploring Children's Prior Ideas
Exploring Children's Prior Ideas of the Topic
Formulating a Unit Based on Children's Questions
Children Involved in Independent Exploration of Concrete Objects Associated with Topic
Children Record Their Questions About Concrete Materials
Children's Questions Used to Formulate the Unit Framework
Exploration of Children's Questions
Exploration of Children's Questions Using Various Approaches
Direct Instruction
Teacher Demonstration
Films
Teacher Directed Activities
Independent Student Exploration
Conclusion
Unit Conclusion
Evaluation
Evaluation (ongoing & cumulative)

children's prior ideas. Therefore, the first phase of this teaching model involves the teacher's exploration of the ideas the children already possess about the science prior to the commencement of the unit. Mrs. L wrote:

> I really have never [found out what the children already know] in science. Yet, it would be interesting to think up some baseline questions to ask before starting the unit.
>
> When you find out what the children know, partly know and don't know about a topic before teaching it, you can use this to find a starting point in the area that is familiar to them, then you can proceed to new areas.
>
> At the end [of the unit] you can compare and see what new learning has taken place, and what aspects still remain unclear.

In this comment, Mrs. L maintains that the teacher's knowledge of children's prior ideas can potentially affect the content and framework of the science unit, and can provide an informal assessment of the efficacy of the science unit. Minstrell (1983) adds that knowledge of children's prior ideas enables the teacher to provide experiences which are directly related to these ideas. Perhaps this could have been important in the initial Sound lesson when some children were able to rationalize that movement was not always a requirement of sound because the teacher was only referring to the objects she presented in class, and was not referring to the objects they mentioned in their initial interviews. Also, if a teacher is aware of the children's prior ideas, perhaps he or she can strive to make direct reference to these prior ideas during his or her demonstrations and lectures, and this might help children to relate the teacher's science to what they already know.

Mrs. L also mentions that some 'baseline' questions could be used to help the teacher explore children's prior ideas.

Sutton (1980) provides a critique and overview of methods researchers have used to explore children's prior ideas; some of these methods are (a) clinical interviews with individual pupils, (b) word association or word-sorting tasks, (c) asking children to write definitions, (d) asking children to choose a preferred statement from several correct ones, and (e) tasks which involve bipolar dimensions on which an idea is rated. Sutton (1980) argues that "the ideal aid would be a set of diagnostic procedures, usable at the beginning of any topic, to give teacher and pupil better insight into the pupil's dominant thought patterns" (p. 119). Sutton (1980) suggests that the most feasible classroom approaches might be:

> 1. Pupil's construction and discussion of their own 'burs' [as contained in mind map diagrams],
> 2. Preparation of different maps or 'overviews' of a topic by the same pupil, but in response to slightly different eliciting tasks, and
> 3. Sorting tasks with words and objects, used to discern not only the categories but also the mental routines most readily available to the learner. (p. 119)

But, perhaps the major consideration influencing the teacher's exploration of children's prior ideas are available time and ease of exploration. This may suggest that the identification of children's prior ideas should be a process which only demands one science period, and perhaps would entail the children recording written comments in response to a restricted number of teacher questions, demonstrations, or scenarios. During the science unit, children might recall additional ideas they already possess about the topic and these ideas may also be recorded on the initial list of prior ideas.

b) Formulating a Unit Based on Children's Questions

The next step in this model would be to involve the children in independent exploration of concrete materials related to the science topic, and concrete materials similar or identical to objects the children mentioned in their prior ideas about the science topic. The children would be required top record the questions they have about these materials, and to make some potential predictions about the answers to these questions. These questions and predictions could be recorded in the children's notebooks, or compiled and listed on charts that every child could view and read.

This idea of initially encouraging children to explore concrete materials and to record their own questions, is an idea found in the LISP model of alternative teaching, in Harlen and Osborne's (1985) model for learning and teaching, and in discussions offered by a variety of researchers. The reasons for beginning with children's exploration of concrete materials and children's questions include:

1. questions can emerge which can be explored in independent investigations (Harlen, & Osborne, 1985, p. 142);
2. questions stimulate other questions and stimulate children's interest and motivation in the topic (Biddulph, & Osborne, 1982);
3. children appreciate lessons based on their questions (Biddulph, & Osborne, 1982);
4. children's predictions provide insight into their thinking and into the way they interpret the questions (Biddulph, & Osborne, 1982; Anderson, & Smith, 1984); and
5. this process assists children in perceiving the

relevance of science (Harlen, & Osborne, 1985; Osborne, 1985).

In this study, the children added that exploration with concrete materials could potentially affect their understanding of the teacher's science, and their belief in the teacher's science. Also, the use of similar or identical concrete objects could affect their perception of relationships between lessons and between tasks, and perhaps could encourage children to make links between the teacher's science and what they already knew.

Some of the questions which emerge from the children's initial manipulation of concrete objects can be used to form the framework of the science unit. In this way, the children will recognize that their questions are valued, and this could affect the children's motivation and interest in the science unit (Biddulph, & Osborne, 1982). Further, Wittrock (1986) has observed that in regard to reading comprehension, a student-generated structure facilitates comprehension more than a teacher-provided structure. If this observation can be applied to science education, then perhaps a science unit which is based on student-generated questions could result in greater student understanding.

What seems most difficult from the teacher's standpoint, is the actual process of deciding which student-generated questions will be included in the unit framework, and which questions will be set aside. Teachers who participated in the LISP studies encountered difficulty with this aspect of their alternative teaching model, and researchers concluded that clear guidelines should be provided to teachers to assist them in question selection (Biddulph, & McMinn, 1983). Perhaps some of these guidelines might include:

1. ensuring that every child in the class has at least one question included in the unit framework;
2. choosing questions which will help children gain a basic understanding about the science topic (Biddulph, & McMinn, 1983);
3. choosing some questions which specifically relate to alternative ideas which emerged from the children's [illegible]ior ideas;
4. choosing some questions which are manageable and appropriate for independent exploration by the students; and
5. choosing some questions which may provide related background information to future science topics.

Perhaps a teacher could react to these guidelines by simply being overwhelmed by the number of considerations that could be taken into account in selecting student questions. A teacher might also be overcome by the amount of time that might be involved in selecting questions, and be defeated by the potentially large number of student-generated questions which might be submitted for selection. Maybe one way to cope with these concerns is to include the children in the selection process by providing them with a list of selection guidelines, or having them provide their own guidelines. Another strategy might be to consult research literature which has listed children's typical questions in a variety of science topics (Biddulph, 1982a; Biddulph, & McMinn, 1983; Biddulph, & Osborne, 1983; Biddulph, Osborne, & Freyberg, 1983; Biddulph, & Roger, 1983; Osborne, Biddulph, Freyberg, & Symington, 1982). These lists of typical questions can provide a guideline for the potential questions that could be raised by the children, can assist in the selection of questions, and can assist with planning what learning resources and materials might be required during the science unit.

c) Exploration of Children's Questions

Once the framework for the unit has been outlined, the exploration of the students' questions can be carried out through direct instruction, teacher demonstrations, teacher-directed activities, and independent student exploration. The percentage of time allotted to any one of these approaches will be dependent on factors associated with the background knowledge and personality of the teacher, and factors associated with the situation of the school.

i) Considerations for Direct Instruction

One purpose of direct instruction could be to introduce information that cannot be explored in some concrete way. The teacher should strive to present this information in such a way as to assist the children in the construction of meaning, and to help the children link this information to their prior ideas, to ideas from other science classes, and to student-generated questions. Wittrock (1985) argues that:

> The more appropriate teaching techniques involve students in the generation of relations between what they know and what they are taught. Teachers do not literally teach in the usual sense of the word. Instead they facilitate learner's generation of meaning and understanding by helping them to relate new and old information and conceptualizations to each other. Even information and concepts which are directly taught to students must still be generated by them for meaningful learning to occur. (p. 265)

Specifically, teaching strategies which might be employed include:

1. initial introduction to lesson purpose through reference

to specific prior ideas and student questions;

2. introduction of lesson content through the use of models, role playing, analogies; possible use of concrete objects similar to those used in previous lessons;
3. interactive discussions about how this lecture might be related to previous classes;
4. children's identification and subsequent discussion of what is hard to believe about the teacher's science; possible recording of what the children wonder about;
5. interactive children's discussion about what would be necessary to increase their belief in and understanding of the teacher's science; and
6. interactive discussion about how the teacher's information might relate to other student-generated questions and future explorations; possible recording of the main points of this discussion.

ii) Considerations for Teacher Demonstrations

At the end of the Sound unit, Mrs. L commented:

> The least modification I would do [in my next science unit] would be to reduce the amount of time I do for demonstrations. [Exclude] some demonstrations, but still [retain] a few demonstrations.

Certainly in this study the children encountered difficulty trying to discern the purpose of some demonstrations, to arrive at a consensus about their observations of some demonstrations, and to provide an explanation for the demonstration that sprang from some personal understanding. Tentative reasons for these difficulties have already been presented in Chapter Seven and many of the teaching strategies outlined for teacher lectures are also applicable to teacher demonstrations. However, the children's comments imply that perhaps it is important to emphasize that

1. demonstrations should include concrete objects which are familiar to the children;
2. children should record their observations, and discuss

their observations with their peers and the teacher;

3. children should exchange ideas about the purpose of the demonstration;

4. there should be a cautious, non-threatening approach to confronting children's alternative ideas (Driver, & Bell, 1986; Driver, Guesne, & Tiberghien, 1985; Mrs. L); and

5. children should discuss how the demonstration is linked to concepts from previous lessons, and to the student-generated questions.

iii) Considerations for Viewing Films

White (1979) has correctly stated that films are useful for relating subject matter to life outside school. Films can also extend children's experience, clarify concepts introduced by the teacher, and repeat classroom activities and demonstrations. The children, however, expressed some reservations about the believability of films because of their prior knowledge about the use of special effects in films, and their suspicions about the unrealistically successful demonstrations contained in films. Perhaps this implies that films should not dominate a science unit, and any films that are shown should be followed by class discussions and contain some activities that the children can verify in the classroom while using concrete objects.

iv) Considerations for Teacher-Directed Hands-On Activities

In this study, the children commented on how the opportunity to manipulate concrete objects could affect whether they understood or believed the teacher's science.

S: [I believe everything] because we did everything.

Johnson, Ryan, and Schroeder (1974) have observed that hands-on activities also have a positive effect on children's attitudes toward science, and they offer that this attitudinal change might be influenced by such factors as the children's perception of control over their own learning, and the children's increased involvement and interaction with the science.

Teacher-directed activities should be based on student-generated questions, should be allowed sufficient time, should contain familiar materials, should encourage the children to share ideas, and should be followed by whole-class discussion. Mrs. L wrote:

> Your timing of the activity parts of the science lessons showed me that I was not devoting as much of the lesson to [hands-on activities] as I somehow imagined. Since time allotted to [hands-on] activities seems so significant to learning in science, I shall be planning more carefully about time in future [science units]. Perhaps I will let the children have time to try out the materials first, with no instruction [from me]. Then I could shape their ideas with brief demonstrations, and then allow them more time for [hands-on] activities.

Driver (1981) warns that children must have "time to think through the implications of observations and measurements made in science lessons. We must realize that our explanations do not spring clearly from the data" (p. 99). Barnes (1976) adds that a delicate balance is needed between the pace of the lesson, the time allotted to hands-on activities, and the deadlines for finished work.

The choice of materials for hands-on activities can also potentially influence children's understanding of the activity. In this study, Victoria and Gordon seemed at times to rely on the use of identical objects to draw connections between different lessons and activities. Equally, the children seemed to have difficulty with perceiving connections between the tin can telephone activity and ideas from previous lessons perhaps because of the novelty of the materials. However, Gordon seemed to have difficulty understanding the marble activity because of the inclusion of objects identical to those he played with during his homelife. Therefore, although all of these observations suggest that children's understanding is derived, in part, from the links they make between familiar aspects of the teacher's science and what they already know, it might be necessary for the teacher to provide time for the children to discuss the connections they make, and discuss how these connections might be related to the framework of the science unit.

During lessons involving hands-on activities, children should be encouraged to exchange ideas with other children in their group, and should also participate in sharing their ideas with the entire class. Barnes (1976) recommends that children should first explain their meanings to each other in the context of their activity group, and this exploratory talk should precede public discussion. Other researchers add that the opportunity to talk with other children in small group discussions, and to listen to other children's ideas can encourage children to reflect on their own ideas, to construct personal understandings, and to modify, extend, and change their ideas (Driver, & Bell, 1986; Harlen, & Osborne, 1985).

There might be other factors which influence the exchange of ideas among children. Sands (1981) has observed that group work might only encourage cooperation at a trivial level and although children do exchange "comments and ask questions of each other, the level of talk which goes on in groups is not very high" (p. 768). Corno and Snow (1986) have commented that "in small, mixed ability groups, higher ability students in effect serve as substitute teachers for students who have trouble learning" (p. 622). LISP researchers have observed that "many pupils and ex-pupils we have spoken to have mentioned the problem of the idle passenger in groups containing large numbers of pupils, and the preference for either working in small groups or individually" (Osborne, Freyberg, & Tasker, 1979b, p. 13).

In this study, group work received a mixed reception and the children experienced moments when they valued interaction with each other, and also enjoyed times when they could work independently.

> C: I sort of helped [my partner], and [another girl] came around and asked me [questions] . . . I guess because she couldn't find anyone else who would help her. Because she wanted to know how you bend [the paper] into the shape of the ear. And right after [that girl] asked, [another girl] asked [me questions].
>
> V: Well, when I give ideas to people they might then go and say, 'Look what I found.' Then [the other children] all surround her and everything. So I just keep my [ideas] to myself.
>
> B: [Working with others] helped me in a way. Like they told me stuff . . . They had good ideas to help me, but I [also] found my own ideas.
>
> G: Well [another boy] thought of the telephone [with the cup and elastics], because you know how [voices] can usually travel through on a string? Your voices like on that one commercial about Little Caesar's on TV? He thought about that so I said, 'Why don't we both put [our cups] to our ears and start strumming on the elastic and see what it sounds like?'.
>
> V: That's one thing about [working with] friends if you were making up ideas. 'Cause you put an idea in and you mix [the ideas] together, and then we've got something.

Perhaps these comments suggest that what might be important to children exchanging ideas and assisting one another is the class atmosphere set by the teacher, the ability levels and personalities of the children involved in each group, the children's anticipation of evaluation, and the teacher's acceptance of a variety of ideas.

v) Considerations for Independent Student Exploration

Mrs. L commented:

> I would also like to [include situations] where the children set a question, and try to test it by [controlling variables] and changing [one variable] at a time. Then I would feel that [the children] are in control of [the activity].

LISP researchers have proposed an alternative teaching model which is based on children's independent exploration of personal questions, and the explanations they propose for these questions. This model involves the children in a six-step strategy for exploring their own questions.

Step 1: children are exposed to an interesting situation related to the science topic

Step 2: children generate questions about the topic

Step 3: children suggest answers to their questions

Step 4: children prepare research proposals based on these questions and seek teacher approval for proposals

Step 5: children carry out an investigation of their question

Step 6: children report their findings to their peers who under the teacher's guidance, provide comments, and ideas for future research (adapted from Biddulph, & McMinn, 1983, p. 1).

Harlen and Osborne (1985) seem close to the LISP alternative teaching model when they recommend a framework involving three phases:

Phase 1: general exploration of relevant objects or events from which questions and hypotheses emerge

Phase 2: investigation of questions

Phase 3: reflection on children's reports which have been compiled throughout the investigation phase of this framework

In this study, the children had the opportunity to compose mini-reports based on a question they had about Sound [see Table 11]. The teacher helped the children generate ideas for their reports by presenting and discussing a chart of potential topics. The main source of information for these mini-reports was library books, and this strategy of gathering information from reference materials is used by scientists and should be equally acceptable in elementary science education (Symington, & Osborne, 1983). However, other questions selected for independent student exploration could involve children in experimental work which requires defining the problem, designing a method of investigation, carrying out the investigation, and forming some tentative conclusions. This independent hands-on inquiry would be sensitive to the children's comments about the importance of personal observation of science phenomena, and the value they place in the opportunity to work with concrete objects.

> S: I always say that if I [can work with concrete objects] I understand it a little bit more than [Mrs. L] just telling us about it.
>
> B: [Working with concrete materials] helps you to understand, because you already tried it.
>
> G: I think using real things helps me [figure out stuff] because I get to actually touch them.

These opportunities for independent student exploration have

TABLE 11

Children's Mini-Report Topics

Aspect	Topic / Question
human hearing	How do deaf people communicate? What causes deafness? What damage can sound do?
human sounds	How does the human voice work?
music	What are the different sounds of music and how do people make them? How do instruments make music?
sound travelling	How does sound travel? What is the sound barrier? Speed of sound.
animal hearing	How do animals use sound to communicate? How do animals hear?
technology	How do radios work? What is Sonar? What is ultrasound? Telephones. How is sound recorded?
insulation	Insulation against sound.

been received enthusiastically by children, and children perceive these explorations to be relevant and meaningful to their lives (Biddulph, & Osborne, 1982; Biddulph, & Roger, 1983). However, independent student exploration requires time, resources, and a certain level of skill, especially if students explore questions which require them to design an experiment. Also, the teacher must cope with maintaining discipline, providing materials, following the children's explorations, providing guidance and questions, and evaluating the nature and extent of the learning taking place. Perhaps this suggests that although independent student exploration can be a valuable part of a science unit, it should be balanced with other situations in which the teacher might feel more comfortable.

d) Unit Conclusion

Finally, the science unit should conclude with the entire class participating in formulating generalizations about the science topic just studied. This would be sympathetic to Renner's (1982) comment that beginning a science unit with "spelling out the principles and generalizations may be deleterious because students must experience the search in isolating the relevant information needed to invent the principles and generalizations" (p. 710).

e) Unit Evaluation

A final consideration about this balanced approach to teaching and learning must lie with the kinds of evaluation and assessment procedures which inevitable occur during science lessons, and at the conclusion of a science unit. Probably the crucial question of evaluation is: How can we move towards assessing and rewarding children's thinking and their personal understandings, and move away from rewarding 'correct' answers which might be only rote learned? It seems conflicting to expect children to be motivated to explore their own questions, and to urge teachers to accept the existence and intelligence of alternative ideas, and then to regress to using exams which require one 'correct' answer to questions generated by adults. Osborne and Wittrock (1983) offer that they "suspect that the nature of much experimental work and typical assessment procedures in science classrooms are such that children are not really encouraged, or find it particularly profitable to attempt, to find links between knowledge" (p. 498). They urge that what is needed are different forms of assessment and they seem to agree with Baird and Mitchell (1986) who maintain that "assessment must positively reinforce the fruits of active learning and clearly discriminate against passive learning" (p. 291).

Mrs. L recognized the dilemma of evaluation and commented:

> I am sure it is really important to validate the [alternative ideas] that the children have, and endorse it somehow. Perhaps [this suggests] the importance of being reasonably neutral about your questioning and not rewarding too much or being negative when you receive answers.
>
> But, can you evaluate [the children's alternative ideas] so that you accept that thinking for the level it is at? Perhaps you could expect [the children] to have an explanation to support their [alternative ideas]. [A teacher could say to the child]: 'Sure, you can say that, but you have to come up with an explanation for why you say it.' Then, if their explanation is not really reasonably well supported, then somehow let them know that.

Harlen and Osborne (1985) seem close to Mrs. L's comments when they suggest what might be indicators of children constructing new meanings and children developing processing strategies. These indicators could form a checklist that could become part of the unit evaluation and these indicators include:

1. children generating explanations and ideas;
2. children relating new ideas (their own and others) to earlier experiences and prior ideas;
3. children basing their statements on evidence, seeking evidence to support statements, and confirming their findings carefully before accepting them as evidence;
4. children being prepared to change their own ideas in light of such accepted evidence; and
5. children reflecting upon how they tested ideas and how testing can be improved. (Adapted from Harlen, & Osborne, 1985, p. 139, 140)

The teacher could gain insight into how the children might have progressed in the unit by comparing the children's final ideas about the topic to their prior ideas, and to the tentative answers the children initially offered to the questions they listed at the commencement of the unit. Although the children may not yet possess 'scientifically' correct ideas, the teacher could still assess whether or not the children could justify any changes that occurred, and whether the children could reflect upon how these changes happened.

This issue of evaluation and the dilemma it presents for teachers who value the intelligent, unique meanings children can give to science concepts is one with which researchers continue to struggle. Perhaps this struggle arises from the conflict which presently exists between a constructivist view of learning and our common authoritarian model of teaching and evaluation. This may suggest that evaluation must also take a balanced approach to children's science and reward the way in which children explore their initial questions, reward student's thinking for the level it is at, reward the ability to recall and explain the generalizations which were formulated at the conclusion of the science unit, and reward the children's ability to apply new ideas to a range of novel situations.

f) Summary Discussion

A balanced approach to presenting science includes ways of presenting science which already occur in science classrooms, but maintains that children will take a more active approach to learning if they can perceive that the science is based on their personal questions, and is relevant to their everyday lives.

What seems to underlie these suggestions for presenting science is the view that children can become more effective, independent learners if they (a) are motivated, (b) perceive that their questions are valued, (c) can exchange ideas with other children and the teacher, (d) take responsibility for their own learning, (e) have the opportunity to manipulate concrete objects, and (f) can generate and test their own ideas.

The teacher has a crucial role in "providing the resources, the physical and social classroom organization, and the encouragement and opportunities for children to learn" (Harlen, & Osborne, 1985, p. 139). However, this role is one to which the teacher can gradually grow accustomed by varying the proportion of time allocated to such classroom events as direct instruction, film viewing, teacher-directed activities, teacher demonstrations, and independent student exploration. In this way, the balanced approach to presenting science is sympathetic to the idea that teachers bring a variety of personal beliefs, different views of knowledge, a range of science knowledge, and individual personality traits to the classroom situation (Barnes, 1976; Harlen, & Osborne, 1985).

Finally, Harlen and Osborne (1985) advise:

> If teacher[s] can adopt the role in [their] classroom of a keen and interested learner wanting to find out more about the world, if [they] can listen to, value, and devise ways to check out [their] own and [their] pupils' ideas, and can encourage [their] pupils to do the same; if [they] can become a 'researcher' both in terms of finding out about things around and in terms of finding ways to improve classroom practice, then science will take its place in the primary school curriculum. (p. 145)

4. Towards Alternative Content for a Sound Unit

Harlen and Osborne (1985) suggest that science content contains two components. These components are the concepts and ideas which are used to describe or explain what is occurring, "and the particular context in which these ideas are made evident" (Harlen, & Osborne, 1985, p. 142). They suggest that two potential contexts for a Sound unit might be musical instruments and noise. The concepts and ideas that could be developed within these two contexts are:

1. how sound is created by vibrating objects;
2. how sound travels through air and other materials; and
3. how hearing involves our eardrums being forced to vibrate by the sound waves. (Adapted from Harlen, & Osborne, 1985, p. 143)

Mrs. L commented that as she taught Sound, she was faced with explanations for events and concepts which were abstract, and could even challenge adults. She thought that what might be more appropriate at the elementary level could be a unit involving pre-sound experiences. She commented:

> You would almost have to call it pre-sound experiences. Or call it music, or, exploring with sound. You could do a lot of these activities, but if they are isolated activities I wonder what the children would make of that?

She added that Sound could also be a home-study unit because she observed that:

> The children seem to learn more about sound by playing guitars, using the stereo, swimming, shouting in mountain parks, and talking on the telephone.

LISP researchers argue, however, that "many science programmes have been built upon adults' views of what children don't know and what they should know" (Symington, Biddulph, Happs, & Osborne, 1982, p. 1). Instead, programs should be based on children's questions. Perhaps there is room in science programs to include children's questions, and yet incorporate the broader view of the science topic which the teacher might possess. In this way, the children can perceive the relevance of the science topic and the value of their questions, and the teacher can use his or her knowledge and insight to select and include questions which can illuminate major concepts and ideas.

At the conclusion of each interview in this study, the children commented about what they now wondered. Their comments revealed that they were puzzled about some aspects of the teacher's science to which they had just been exposed, and they wondered about topics and questions which seemed related to the science lesson. Also, during and after some science lessons, some of the children used the science materials to explore additional questions which occurred to them. These comments, questions, and explorations illuminate some of the potential interests these children had about Sound, and can provide a potential "demarcation of what curriculum is possible" (Barnes, 1976, p. 88). Some of the children's questions are presented in Table 12.

C. Implications for Pre-Service Teacher Education

Mrs. L commented that, based on her observations of the influence of hands-on activities on the children's understandings and beliefs, she would prefer to see an increased amount of time devoted to doing activities in elementary science methods courses:

> Can the elementary science methods course be a [year-long, six credit] course? I think you would find people signing up for it. However, even if you expanded [the course] into a six credit course with a lab component, you would still have to make some decisions about what you were going to do because the time would still be limited.
>
> I have wondered about the value of having one really strong unit, something like Colored Solutions, or Sound, or an Electricity unit. A lab course would have to be patient enough to address one unit thoroughly, but after that, can [pre-service teachers] transfer what they have done to another content area in science? I don't know.
>
> One of the other ways to do it practically is to highlight activities from different science content areas. But, then that becomes [overwhelming]. Also, I want to have a framework that is pieced together so I feel that I know something about the subject at the end [of the course], instead of a number of little showy things.
>
> I guess I would almost say a whole unit would be more useful than dribs and drabs, because when you think back [to the course]. although you remember highlights, you can't do highlight after highlight from different units. Your [science] would be over by the end of September.

Mrs. L added that pre-service teachers should be exposed to literature concerning children's alternative ideas, and should visit elementary science classrooms to gain insight into planning science

TABLE 12

A Selection of Questions the Children Asked During a Teacher-Directed Sound Unit

Aspect	Questions
tuning forks	Why does a tuning fork make water splash? Why does a tuning fork vibrate when you hit it?
amplification	Can loud screams be heard from far away? How come a cup makes an elastic sound louder?
history / linguistics	How did people originally find out an explanation for sound? Why is sound called sound?
sound travelling through matter	How come sound moves faster through hard solids than through soft air? How long can the hose be before you can no longer hear the other person? Can you hear better with a thick or a thin string on the tin can telephone?
echoes	How do echoes repeat what you say? How does sound bounce?
human hearing	How does an ear work? How does a doctor put tubes in your ears?
animal hearing	Do animals with big ears hear better than animals with smaller ears?
speed of sound	How come you see sticks hitting together before you can hear the sound?
pitch	How do you get the correct pitch using homemade instruments?
insulation	How do walls and tiles absorb sound?

units, organizing materials, and working with children. Also, pre-service teachers could generate their own simple question about some science topic, investigate this question, and then report their findings to their peers. This would provide pre-service teachers with some insight into selecting manageable questions, planning experiments, and insight into the experience of reporting ideas to an audience.

Other researchers have made suggestions about pre-service teacher education and some of these suggestions include:

1. analysis of conditions and philosophies which underly school life and difficulties for implementing a constructivist view of learning and teaching;
2. an introduction to children's ideas, then scientists' views, and then clarify where their own views lie with respect to these two views (Osborne, Bell, & Gilbert, 1983, p. 11);
3. exposure to children's ideas, scientists's views, and suggested investigations that can be used in class (Symington, & Osborne, 1983);
4. exposure to kinds of questions asked by children (Symingont, & Osborne, 1983);
5. guidance on how to select worthwhile topics and questions (Symington, & Osborne, 1983);
6. direction about how to assume the more active role of encouraging, challenging, and suggesting (Symington, & Osborne, 1983);
7. direction about pupil management (Symington, & Osborne, 1983);
8. undertake small scale investigations into children's science in schools and the views of their teachers college peers (Fensham, Garrard, & West, 1981; Osborne, Bell, & Gilbert, 1983); and
9. guidance about how to assess if children's ideas have changed (Symington, & Osborne, 1983).

Finally, apart from investigations and presentations, pre-service teachers might perform during class time, there are two ideas for assignments that might prove particularly worthwhile. The first assignment would require pre-service teachers to interview a child about some science phenomena, and to elicit the child's ideas and explanations about that phenomena. In this way, the pre-service teacher would gain direct insight into the existence of children's science, and into the variety of ideas which children may bring to a science unit. A second assignment would involve asking a child about the questions he or she has about some object or phenomena. Guidelines and directions for eliciting children's questions have been presented by Symington, Biddulph, Happs, & Osborne (1982) and some of their directions include:

1. having the child manipulate several related objects e.g., interesting pieces of wood;
2. asking the child to suggest things that a scientist might know about this wood, but he or she did not know;
3. recording the child's suggestions (audiotaped and long-hand);
4. asking the child which suggestions he or she would be interested in exploring; and
5. asking the child how he or she would explore these suggestions.

These questions could form the basis of a discussion about children's thinking, could be used to write a report about how a teacher could select one of these questions and guide the child to explore the question, or could even be incorporated with questions compiled by other pre-service teachers to form lists of questions children may propose for various science topics. These lists of questions could help pre-service teachers anticipate questions their own students might ask someday, and this could assist in the planning and execution of a science unit.

D. Ideas for Future Research

At the conclusion of this study, Mrs. L and I reflected on the methodology used, and the findings, and implications which emerged from the Sound unit. We agreed that there were many issues about which we still wondered, and that this study could become a starting point for explorations involving additional interview questions. Also, we thought this study suggested the importance of continuing to examine children's learning, and the role of affective factors upon this learning.

Our review of the interview transcripts, and my discussion of the gaps which remained in our knowledge of children in science, led us to believe that future studies involving interviews could be expanded to include:

1. questioning children about what puzzled them as they participated in the activity tasks [to avoid problems with lesson recall in the interview situation];
2. questioning the children about homelife science experiences [to assess potential affect on attitudes, prior ideas, and ability];
3. probing the children's prior ideas as lessons progressed e.g., Have you done or heard about something like this before? [to probe for prior ideas that did not emerge in the initial interview];
4. asking questions which would require the children to transfer new learning to different situations [to expose level of understanding, potential subsumption or adoption];
5. asking questions which could expose the creative, imaginative elements in students thinking e.g., What did you think about before you got that idea? [to assess content and pervasiveness of this element];
6. asking children what aspects of the lesson they might

want to pursue independently [to assess their interest in the lesson and the concepts presented]; and

7. asking children if there was a part of the lesson they would want to do more or less of [assess personal preferences].

Mrs. L and I also had some questions and ideas about children's learning in science which seemed to have the potential to become the focus of future studies. Some of these questions and ideas included:

1. To assess what children have learned and understood, and perhaps to gain insight into subsumption or adoption, a group of children could be studied as they attempted to teach some selected Sound concepts to a group of children from the preceding grade level.

2. How long do children remember the concepts they studied during the Sound unit? What factors influenced the children to remember these concepts?

3. Implementing the balanced teaching model presented in this chapter and attempting to assess the nature and degree of the children's understanding. Can the children's understandings be compared to the understandings they derived from this study?

4. How does language mystify science for children? What practical strategies can teachers use to minimize this mystification? How can Schutz (1971) add to our understanding of language in science?

5. What influences children to change their ideas? Do children progress through Hewson's (1981) stages, or is change something that is much more personal and illogical?

6. Is the sequence of activities important in a Sound unit? Or, do children generate their own framework at some critical point unrelated to a logical order?

7. What else might be involved in the evolution of personal understanding?

Within this area of children's learning, Mrs. L and I were particularly interested in the role that affective factors seemed to play in the children's struggle for personal understanding. We thought that a greater exploration of this area might extend the constructivist view of learning, and the Generative Learning Model. Some of the factors we wondered about included:

1. What role does caring about the science play in children understanding science? Does this vary from day to day, and between tasks and topics? Do some children care more than others, and why?
2. How might locus of control be related to rote learning in science, or striving towards a personal understanding of the science?
3. What role does perseverance play in children understanding science?
4. What are children's belief systems and do these systems affect their understanding of science?
5. How might willingness to take risks be related to understanding science?
6. How can children be encouraged to wonder? Is wonder important to understanding science?
7. Curiosity and motivation - Who has it and why?
8. How might genetics be involved in influencing and/or forming these affective factors?

Finally, perhaps this apparent conclusion to the study is really the beginning of an exploration into how children construct understandings of the teacher's science, how the teacher's presentation of the science is influenced by the existing school system, and how collaborative methodologies may serve to promote a conversation among participants which is a metaphor for the way in which children construct personal meaning. In this respect, when children wonder about the teacher's science, and talk about how they construct meaning of the teacher's science, maybe they are also speaking about how all of us relate to and try to understand the world. We all wonder about the world and in private musings and public conversations we try to move towards a greater understanding of the world and our place within it. This dialogue is not some strict cognitive exercise but is inevitable influenced by affective and situational factors. Therefore, when we talk about how children understand science in school classrooms, maybe we are also talking about how we all attempt to understand the world, and this suggests that we should recognize that children's attempts to make sense of their science experience mirrors how we all approach the world, and involves all that we are as human beings.

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APPENDICES

Appendix A

Study Summary for Initial Teacher Meeting

Children's Learning in Science: A Collaborative Study

Purposes

1. The primary purpose of this study is to explore how and what a small group of children learn in elementary school science. This exploration might help to answer the question: How do children construct meaning in elementary school science?

2. A secondary purpose is to share in the experience of collaborative research and discuss how this approach to research might allow for additional insight into the complexity of learning and teaching science. This might help to answer the question: How can collaborative research benefit our understanding of classroom science?
   In this study, collaborative research means three groups of people trying to make sense of children's learning: 1) the children, 2) the teacher, and 3) the researcher.

Methodology

1. Collaboration means people working together towards some common goal in an atmosphere of respect. Collaboration suggests a flexible methodology that can be changed and amended as the study progresses.

   e.g.,The children, the teacher, or the researcher may recognize problems with the initial plans for this study and may suggest that interview questions be changed or that interview times or format be changed, or that participants should have more written input into interpretations made from the interviews, etc.

   Therefore, I anticipate a gradual evolution of the methodology as the study progresses.

2. The primary concern of this study is to try and understand how a small group of children construct meaning in school science. In other words, how and what do children learn during science class.
   I believe that the best way to begin to understand the experience of learning in science is to talk to the children before, during, and after their classroom science lesson.

   a) Before the lesson: What do the children already know about the topic? How did they come to know this information?

b) During and/or after the lesson: What was their specific task?. How did they cope with the task? How did they solve any problems? What did they learn? What puzzled them? Were any of their initial notions changed or modified? What questions do they now have?

Study questions and the children's responses will be recorded on audiotape and I will make written interpretations of the interview. These interpretations will be given to the children who will be asked to make any changes to the document as they see fit.

3. Due to my interest in how and what children learn during science class, it is important to ask questions which are specific to the actual science lesson. In order to assist in recalling these lessons, I will be writing down the main points of the lessons as they happen.

e.g., What is the specific topic/lesson intent? What questions arose? What was the set task? How did the students approach and cope with the task?

These lesson portrayals will be made available to the teacher who will be asked to read and respond to them.

4. The teacher is also an important part of the study. He or she possesses more knowledge of the classroom and the children than I ever will.
In order to more fully explore the teacher's experience of student learning and his or her participation in a collaborative study, a number of interviews will be carried out.

a) Students' learning: What was the intent of the lesson? What does the teacher expect the children will be able to do at the end of the lesson? What did the children learn? How does the teacher know what the children have learned? What difficulties did the children have with the lesson? What were they confident about?

b) Collaboration: What was the teacher's experience of collaboration?

Study questions and the teacher's responses will be recorded on audiotape and I will make written interpretations of the interview. These interpretations will be given to the teacher who will be asked to make any changes to the document that they see fit.

The teacher will also be asked to help in the collection of documents which might help to more fully explore how and what the children learn.

e.g., tests, worksheets, xerox copies of student notebooks

The teacher will also be asked to read and respond to the thesis prior to it being submitted to the examining committee. Some responses which might be anticipated are:

1) asking for sentences to be re-worded
2) asking for sentences to be deleted
3) asking for sentences to be added
4) asking to add his or her own written comments to mine

Appendix B

Sample Lesson Description Notes and Classroom Observation

November 20, 1987

T = Teacher
C = Child

1:16 p.m. Children enter the room after the lunch break. The teacher gets some wood blocks and sticks from the cupboard and then lifts some short lengths of two by fours out of a box.

T: Today we are going to be finding some echoes. Does anyone have any ideas about this or has already found a good spot?

Christa: In the gym.

T: We are going to use the wooden blocks from music.

C: Around the part where it is crowded.

C: Going in the gym near the stage, pull out the drawers, and you yell into them.

T: Has anyone tested out their ideas? Tell us how you tested your ideas.

C: When I was walking home, I yelled to [Gordon] and it echoed back.

C: I heard an echo up on the hill.

T: What are the conditions that are necessary for an echo? What is an echo? Where have you already heard an echo?

C: In a cave. We shouted or really we just talked.

T: So, you said a word and then you heard it back.

C: In the mountains by Jasper. At the ski valley.

T: You shouted?

C: Yes, on the ski hill. I yelled, 'Mom'!

C: By the forest in the ravine there is a really high hill. You can shout from there.

T: What do you hear?

C: I heard 'A.J." back.

T: How come you could hear it again?

Gordon: It hit the thing and then went back to you.

T: What hit what?

C: The sound hit the mountain and then you heard it back again.

C: Devil's leap. Down in the ravine.

C: Libya. My grandparents have a building shop and when they hit the hammer you can hear it loud. [Can hear it again].

C: Stony Plain. We had a big front porch on our house. [continues on with her story]

T: Could you hear the exact words back again? Sometimes you can hear it say it again. Where outside can you hear echoes?

C: Daycare. If you go outside there and yell by the wall.

T: Do walls help?

C: You make the sound bounce off the wall.

T: Where is a big wall?

C: Washroom.

T: Where outside?

Christa: Outside of the gym.

The teacher talks about appropriate behavior for an outdoor science class.

T: We will try in the film when they were standing by the train tracks. We will get someone to go far away and then we will get them to strike the wood then the rest of us will watch you.

1:35 p.m. The class goes outside. Christa and Samantha go ahead of us to check out the echoes in the interior of the gym. Victoria is one of the children who is given music blocks and sticks to hit together. We all gather outside the gym wall on the playground. Gordon has two sections of two by fours in his hands and he starts jogging out to the far reaches of the playground.

The class stands right next to the gym wall and the sticks are struck together. They cannot hear an echo.

1:36 p.m. T: See where you can find an echo outside the gym wall. How many paces away will we have to go until we will start hearing something?

Samantha and Christa come running outside and report their findings about the interior of the gym.

Samantha: No echoes.

Christa: The gym was full of people.

We count off ten paces into the field away from the gym wall and a student bangs the sticks while the rest of the class listens for an echo.

C: I hear an echo.

T: From where?

C: It's not from the gym.

C: Down there. [points behind to a row of houses]

We count off five more paces and then the children hit the sticks again and we listen.

C: You can hear it over there. [points to houses surrounding the playground]

C: There is no space for it to go back.

C: We were too close. Come back. We couldn't hear it.

We count off five more paces and hit the sticks again.

T: Was it any different?

C: It comes at a different time.

C: It comes later.

We count off five more paces and hit the sticks again.

C: You can hear it a little better.

T: Is it hitting other places besides the gym wall?

C: The houses.

T: It seems to be bouncing off a lot of places.

We count off another five paces and hit the sticks again.

T: Where was it louder? Which direction? It doesn't seem to be coming from the gym anymore.

C: Over in the community center.

C: Back there.

C: Hard to tell.

The teacher sends two boys over to where Gordon is, far out in the field. They are to tell Gordon to hit the sticks, count to 20, hit them again, and to repeat this 10 times.

The boys run across the field, deliver the message and we stand still and observe Gordon who is just visible at the furthest end of the playground.

T: Do they hit together before you hear the sound?

C: YES!!!

C: The sound has to travel.

Bob is sent to tell Gordon to hold the two by fours up high when he is hitting them.

Gordon comes running back and listens to Bob who has remained out in the field and is now hitting the two by fours together.

1:57 p.m. We go back inside the classroom.

2:05 p.m. Using the blackboard, the teacher draws a diagram of the gym wall and the various positions we took in the field while trying to hear the echoes.

T: Using chalk, what was going on to explain how we heard an echo from the gym wall which then got louder and the different places we stood?

A boy comes to the blackboard and draws a line to represent the sound waves going from the sticks that were hit together, then to the wall of the gym, and then back to our ears.

T: How many steps did we take before we heard an echo?

C: About 15 steps.

T: 15 times 2 feet. We were about 30 feet out. Then we heard an echo from the gym.

C: We could hear it but it happened too soon.

T: Could you explain that?

C: Sound waves travel pretty fast.

T: When we were close, it travelled so fast we couldn't even tell if there was an echo.

T: [referring to chalkboard diagram] When we were further out it took longer and we could distinguish the time.

T: Now, what about the blocks with [Bob and Gordon].?

Victoria: When they hit the blocks, two seconds later we could hear the noise. If you do it soft first, then it gets louder.

C: Seeing travels faster than sound.

T: [summarizes the previous statement] Are there any animals that use echoes?

C: That great Canadian animal, the beaver. It slaps the wood with it's tail.

C: Moose. They make a big loud noise and it echoes back.

C: Bats or owls.

T: [talks about bats]

C: Dolphin.

C: Whales.

T: People use echoes too. Why do ships use echoes?

C: To tell if there is another ship around or not.

T: Some fishing vessels use SONAR. [she gives a brief explanation using a diagram on the chalkboard]

2:15 p.m. Recess bell rings.

Teacher's Written Comments About the Lesson

I have taken classes out to find echoes there for the last four years, but this class wins the prize for giddiness. It is so important to be quiet and listen in this activity. They could scarcely have noticed much about the echoes. This is an activity more successfully done by oneself or with a partner. I might try sending them out by themselves, two or three at a time. I wonder what they would do out there?

Anyway, we were all intrigued to see for ourselves the time lag between light waves and sound when the boys went to the far end of the field and clapped the boards together. It would be interesting to use binoculars and see if we could time an increased length of interval if a student went even further away. (higher grade level) I had no idea whether we would notice the phenomenon at that distance or not. It worked out well.

[One boy] could explain why we don't hear echoes close to the gym wall but could, further out. I would like to know if he just thought of that or where he got the idea. I wonder if the class as a whole realized what we were doing out there.

Appendix C

Children's Individual Interview Questions

A. Lesson Purpose

1. Lesson Purpose

What was today's science class all about?
What were you hoping to find out?

2. Teacher's Perceived Purpose

Why did the teacher want you to do today's lesson?
I wonder why the teacher thought it was important to ____?

B. Coping with the Activity Task

1. Task Description

What did you do first?
Then, what did you do?

2. Getting Ideas

How did you get the idea to do that?

3. Perception of Level of Task Difficulty

Did you have any problems trying to do the activity?
What was hard about the things you did?
How come these things were hard?
What did you do about these hard things?
What was easy about the things you did?
How come these things were easy?
Have you done anything like that before?

4. Working With Others

Did you work with any other students today?
If not, how come you worked on your own?
What was it like to work with the other students?
Did working with other children help or not help you with today's lesson? How come?
What did the other children say or do that helped or didn't help you?

5. Working With Concrete Materials

Did working with the actual materials or things help you understand the lesson? How come?
Is there any difference between doing the activity and watching the teacher do a demonstration or watching a film?

6. Teacher Influence

Did the teacher say or do anything that helped you do the activity?

C. Understanding the Lesson

1. Perception of Learning

What did you learn from this lesson?
How do you know that you learned that?

2. Perception of Understanding

What did you understand about this lesson?
How do you know that you understood that?
What will it take for you to understand that?
Was there anything that you learned today that you did not understand?

3. Believing

Was there anything that you did not believe about today's lesson?
What would it take to get you to believe?

4. Changing

Have any of the ideas you started out with about Sound changed because of what you heard or did today?
How come you changed your mind about that?

5. Making Connections

Is there any connection between today's lesson and your other science lessons?

6. Further Questions / Wondering

What do you wonder or puzzle about now that you have done today's lesson?

7. New Vocabulary

What does _______ mean to you?
Tell me what you now know about __________?

Appendix D

Sample Individual Child Interview

November 20, 1987

R = Researcher
S = Samantha

1. R: Why did the teacher want you to learn about echoes in science today?

2. S: To show how when you learn it hits against the wall and comes back to you and then you can hear it clearly. To know more about echoes. The sound of echoes.

3. R: [gym wall] What was that all about?

4. S: We saw if we could hear better and better as we got farther from the gym. So we started at the beginning very close to the gym on the sidewalk next to the gym, then we hit it, and you couldn't hear it. Then you went back ten steps and then you hit it and you could hear it a little bit. And then with the next one you could hear it a little bit louder the next one louder and then it goes on and on louder, louder, louder.

5. R: Could you figure out how come it went louder?

6. S: Maybe because the first time it bounced over us or too fast for us to hear. Because we were very close. The second one was a little bit better because we were farther away.

7. R: Were there any other echoes going on out there? [besides the gym wall]

8. S: By us making it?

9. R: Any more places that you heard echoes from?

10. S: I heard from the sides and the back. I didn't really hear it from the gym.

11. R: [Gordon and Bob in the field] What did you see going on there?

12. S: I saw like, [Gordon] first took the sticks and then he hit them and then we counted to two and then we heard the noise. Then he had to count to twenty again.

13. R: Did you figure out why you counted to two before you heard

the noise?

14. S: Because the sound didn't travel very fast. [Mrs. L] says the sound travels fast but he went pretty far away.

15. R: So the reason why you saw the sticks hit and then you heard it was because sound travels fast?

16. S: It was a long ways away, not as long as the film had it though. And for each second that we counted I guess it went half way and the next second the sound came to us.

17. R: Was there any difference between watching it on the film and getting to try it out in the school ground?

18. S: Not really.

19. R: Did it help you understand or did it make no difference?

20. S: Just one difference. In the film I didn't see the trigger go off. I heard the bang, but I didn't see it. 'Cause they were just showing the bang and the little boy looking at it.

21. R: And what happened today?

22. S: We could see it, we could see the blocks hitting together and then waited two seconds and we could hear the noise.

23. R: So, did that help you that you could see the blocks?

24. S: Yah.

25. R: Did you have any problems trying to figure out what was going on today?

26. S: Not really. But, it was hard finding the echoes.

27. R: Did the other kids say anything that helped you?

28. S: Not really. They just yelled and something like that.

29. R: Did the teacher do or say anything that helped you today?

30. S: She did take us outside and then she told us what to do and that helped me.

31. R: What did you learn today?

[illegible]: That sound travels fast. If sound bounces off a wall and you're right next to a wall, you can't hear it. And if you're far away from a wall and maybe hitting something, you could hear it better. A loud hit too. A hammer.

33. R: What did you understand today?

34. S: What we had to do. That's mostly what we did.

35. R: Was there anything that you learned that you didn't understand?

36. S: How come it doesn't come right to us when we see it. The sound? We see it and then the sound comes to us. I don't get that.

37. R: Anything that you didn't believe today?

38. S: We had a short science period. So I believe mostly everything because we did all of that. When [Victoria] said something about twirling on the [volleyball poles in the gym] you can hear through the metal.

39. R: Have you tried that?

40. S: Yah.

41. R: Do you think that has anything to do with what you are doing in science class right now?

42. S: Like, that film, it showed the boy taking the stethoscope and putting it on the metal and this other boy was hitting the track with a hammer. And he could hear it while he was looking at it too. We heard that too.

43. R: Have any of your initial ideas changed? [we consult her initial interview]

44. S: [mountains, walls, washroom] No, I tried the washroom and it didn't echo so I don't think so. But, I wasn't far away from the washroom, I was inside the washroom. [she is unsure]

45. R: Any connection between what you learned about echoes and what you learned in your other science classes?

46. S: Today we had a connection in that film and that was another day. In the film we learned hitting the stick from far away and you can see it but not hear it. But, not really with the echo.

47. R: Is there anything you wonder or puzzle about?

48. S: How come you can't hear it while you see it. I was wondering. I understand about echoes but not the sticks

hitting together.

Appendix E

Sample Summary and Interpretation of Child Interview

November 20, 1987

S = Samantha

A. Lesson Purpose

1. Teacher's Perceived Purpose

S: To show how when you learn it hits against the wall and comes back to you and then you can hear it clearly. To know more about echoes.

B. Coping with the Activity Task

1. Task Description

a) Gym wall: S: We saw if we could hear better and better as we got farther from the gym. So we started at the beginning very close to the gym on the sidewalk next to the gym, then we hit it, and you couldn't hear it. Then you went back ten steps and then you hit it and you could hear it a little bit. And then with the next one you could hear it a little bit louder then the next one louder and then it goes on and on louder, louder, louder.

S: Maybe because the first time it bounced over us or too fast for us to hear. Because we were very close. The second one was a little bit better because we were farther away.

S: I heard from the sides and the back. I didn't really hear it from the gym.

b) Gordon and Bob in the field: S: I saw like, [Gordon] first took the sticks and then hit them and then we counted to two and then we heard the noise. Then we had to count to 20 again.

S: Because the sound didn't travel very fast. [Mrs. L] says the sound travels fast but he went pretty far away.

S: It was a long ways away, not as long as the film had it, though. And for each second that we counted, I guess it went half way and the next second, the sound came to us.

2. Perception of Level of Task Difficulty

S: Not really. But, it was hard finding the echoes.

3. Working with Others

S: Not really. They just yelled and something like that.

4. Teacher Influence

S: She did take us outside and then she told us what to do and that helped me.

C. Understanding the Lesson

1. Perception of Learning

S: That sounds travel fast. If sound bounces off a wall, and you're right next to a wall, you can't hear it. And if you're far away from a wall, and maybe hitting something, you could hear it better. A loud hit, too. A hammer.

2. Perception of Understanding

S: What we had to do. That's mostly what we did.

a) Film vs. activity: S: Just one difference. In the film I didn't see the trigger go off. I heard the bang, but I didn't see it. 'Cause they were just showing the bang and the little boy looking at it.

b) Learn / Not understand: S: How come it doesn't come right to us when we see it? The sound. We see it and then the sound comes to us. I don't get that.

3. Believing

S: We had a short science period. So I believe mostly everything because we did all of that. When [Victoria] said something about twirling on the [volleyball poles in the gym] you can hear through metal.

4. Changing

S: [in reference to her prior ideas about mountains, walls, and washrooms] No, I tried the washroom and it didn't echo so I don't think so. But, I wasn't far away from the washroom, I was inside the washroom. [she is unsure]

5. Making Connections

S: Today we had a connection in that film and that was another day. In the film we learned hitting the stick from far away and you can see it but not hear it. But, not really with the echo.

6. Further Questions / Wondering

S: How come you can't hear it while you see it. I was wondering. I understand about echoes but not the sticks hitting together.

Appendix F

Group Permission Letter

October, 1987

Parent or Guardian of ________________

I am a graduate student in Elementary Science Education and I am currently engaged in thesis research for my doctoral degree. My thesis is entitled 'Children's Learning in Science: A Collaborative Study' and I am interested in exploring how and what elementary children learn during their school science experiences.

[Mrs. L] has agreed to cooperate with this study and therefore the class that I will be studying is the one in which your child is enrolled. During the study I will be making observations of the science classes, carrying out a number of interviews with a small sample of children from the class, and briefly talking with all students during science class. In this way I hope that every child in the class will feel included in the study and recognize that his or her ideas and opinions are valued. At this time I would appreciate it if you would grant me permission to occasionally talk with your child as he or she participates in science class. If your child's comments should appear in the eventual thesis write-up, anonymity is assured.

I hope that this study will contribute to our understanding of elementary science from the perspective of the students, and help to assist in future program planning and curriculum development in elementary science education.

Yours sincerely,

Brenda J. Gustafson

Phone:

- -

I give my permission for ______________ to take part in classroom conversations with Brenda Gustafson for the purpose of being included in the study entitled: Children's Learning in Science: A Collaborative Study.

____
Parent/Guardian Signature

Appendix G

Individual Permission Letter

October, 1987

Parent or Guardian of ________________

I am a graduate student in Elementary Science Education and I am currently engaged in thesis research for my doctoral degree. My thesis is entitled 'Children's Learning in Science: A Collaborative Study' and I am interested in exploring how and what elementary children learn during their school science experiences.

The classroom that I am studying is the one in which your child is enrolled. During the study I will be making observations of the science classes, briefly talking with all students during science class, and carrying out a number of interviews with a small sample of children from the class. I would appreciate it if you would grant me the permission to include your child in this small sample and conduct several interviews with your child at school. This will involve discussing the experience of learning in school science that your child has and exploring how this learning takes place. All study participants are assured of anonymity in the eventual thesis write-up.

I hope that this study will contribute to our understanding of elementary science from the perspective of the students, and help to assist in future program planning and curriculum development in elementary science education.

Yours sincerely,

Brenda J. Gustafson

Phone:

I give my permission for ______________ to take part in school interviews for the purpose of being included in the thesis entitled: Children's Learning in Science: A Collaborative Study.

____
Parent/Guardian Signature

Appendix H

Time Schedule

Date	School Visit Time	Topic of Lesson or School Visit	Interview
Oct. 16	3:30 - 4:45 p.m.	Initial meeting with Teacher	Teacher
Oct. 19	8:40 - 10:15 a.m.	Initial visit to classroom	-
Oct. 20	12:20 - 1:15 p.m.	Teacher introduces the study to the class of children	-
Oct. 21	3:15 - 3:45 p.m.	Introduce the class to the study; distribute permission letters	-
Oct. 22	9:30 - 10:15 a.m.	Making Magnet Questions; selection of participants	-
Oct. 23	2:20 - 3:30 p.m.	Magnet Exam	Teacher
Oct. 26	8:53 - 10:15 a.m.	Children's initial ideas about Sound	Children
Oct. 27	9:00 - 11:00 a.m.	Introduction to Sound Unit	Teacher
Oct. 30	9:00 - 10:15 a.m.		Children
Nov. 2	9:00 - 10:15 a.m.		Children
Nov. 9	1:00 - 3:30 p.m.	How is Sound Made?	Children
Nov. 10	9:00 - 12 noon	Vibrations	Children
Nov. 12	9:00 - 10:15 a.m. 2:00 - 3:30 p.m.	Making Sounds Louder	Children
Nov. 13	1:00 - 3:30 p.m.	How Does Sound Travel?	Children
Nov. 16	9:00 - 10:15 a.m.		Children
Nov. 17	9:00 - 10:15 a.m. 1:00 - 2:30 p.m.	How do we Hear?	Children

Date	School Visit Time	Topic of Lesson or School Visit	Interview
Nov. 19	1:00 - 3:30 p.m.	Film: Learning About Sound	Children
Nov. 20	10:30 - 11:15 a.m. 1:00 - 3:30 p.m.	Echoes; Speed of Sound	Children
Nov. 24	9:00 - 10:15 a.m. 1:00 - 3:30 p.m.	How Does Sound Travel?	Children
Nov. 26	9:00 - 10:15 a.m. 1:00 - 3:30 p.m.	How Does Sound Travel?	Children
Nov. 27	1:00 - 3:30 p.m.	Introduction to Pitch	Children
Nov. 30	9:00 - 10:15 a.m. 1:00 - 3:30 p.m.	Exploring the Concept of Pitch	Children
Dec. 1		Film: Animals Hear in Many Ways	
	1:00 - 3:30 p.m.	Lesson: Exploring Pitch	Children
Dec. 7	1:00 - 3:30 p.m.	Lesson: Evaluating Sound Film: Noises	Children
Dec. 8	9:00 - 10:00 a.m. 1:00 - 3:30 p.m.	Insulation; Unit Review	Children
Dec. 10	9:00 - 11:00 a.m. 3:00 - 6:00 p.m.	Sound Unit Quiz	Children Teacher
Dec. 16	9:00 - 11:30 a.m.	Final individual interview	Children
Dec. 17	1:00 - 3:30 p.m.	Final group interview	Children

Appendix I

Children's Questions About the Film: Learning About Sound

November 19, 1987

Christa's Questions

I learned that ...

Sound travles [sic] 10x faster though [sic] steel then [sic] air.
You can use a laser beam to see the vibration of a tuning fork.

Some questions I have are....

1. Why is sound called sound?

Samantha's Questions

What I found interesting in the film is that a oscilloscope because it shows how high it goes and how low it goes. [sic]

Questions:

1. How does the synthizer [sic] get about the same sound as the real instrument?

Bob's Questions

I learned that if you put a bell inside a jar and you fill up the jar with smoke and the bell rings you will not hear it. You won't hear it because there is smoke in the jar and you can not hear sound when air isn't around the object that makes the sound.

Some questions I have are:

1. I wonder how strong sound goes through thick solid?

2. Why does metal vibrate better then [sic] plastic?

3. I wonder why sound travels so fast?

Victoria and Gordon did not record any comments or questions in their notebooks.

Appendix J

Children's Paragraphs About Tin Can Telephones

Victoria's Paragraph

It was neat to use tin can telephones. First thing my partener [sic] and I did was I went to the gym and [Samantha] was in the hall I yelled as hard as could [sic] and said 'How Old Are You'. She answered and I heard. Next thing we did was we used the hose. I could hear [Samantha] better by takeing [sic] off the funnel. And that's what happened.

Bob's Paragraph

What we did with the tin can telephones was a lot of stuff. First we talked to each other in the tin cans. We could hear each other too. After we plucked the string and it sounded real funny. We each got a turn to pluck the string. After [Mrs. L] came and rubbed coat hangers on the string. It made a neat sound. Then I rubbed my hand on the string and it made a quiet sound. We found out that if you cover the bottom of the can you will find out that you are not letting the can vibrate.

Samantha's Paragraph

When I used a tin can telephone we went to the library and we stretched the string and then we talked through it then we could hear clearly through it. Then we went to the Gym and we could hear much more better then [sic] when we were in the library. Then we came to the room and tried talking through the hose. We could only hear little things like Eeeeee and stuff like that. That happened because the hose is hollow [redacted] when we used the Tin Can Telephone the string is solid. That proved that sound travels faster in solids then [sic] air.

Christa's Paragraph

I talked though [sic] the Tin Can Telephone with [Victoria and Samantha]. Sometimes we could only hear though [sic] the air. We tried the hose but we couldn't hear veary [sic] well.

[Gordon did not write a paragraph about his experiences.]

Appendix K

Sound Card Summary

December 8, 1987

Statement	Victoria	Christa	Bob	Gordon	Samantha
Bell jar and pump experiment	1	3	1	1	3
Tuning forks: see, hear, feel	3	3	1	2	3
Noise pollution. What can we do to reduce noise?	3	3	1	2	3
Pitch: Sound can be high or low. Higher pitch means faster vibration. Lower pitch is lower vibration.	1	3	3	3	1
The ear, and how do we hear.	3	3	3	3	3
Blowing in bottles, tapping beakers, snapping sound sticks, twanging elastics, playing combs.	1	1	1/3	1	1
Does sound travel better through solids, liquids, or gases?	2	2	2	2	2
Finding an echo from the gym wall.	2	3	3	2	3
Molecules pass on the sound wave energy.	2	2	2	2	2
Transmitting sounds through tin can telephones.	3	2	2/3	3	2

Key

1 = What causes sound?; How is sound produced?; What are the characteristics of sound?

2 = How does sound travel?

3 = How is sound received?; How do we hear?

Statement	Victoria	Christa	Bob	Gordon	Samantha
Vibration is a rapid to and fro movement	2	1	2	1	1
The push energy of marbles rolled in a track is passed from marble to marble	2	2	2	1	2
Wave action in a stretched Slinky	2	2	2	1	2
Sound is energy	1	1	1	1	1
Sound waves travel slower than light waves. We see lightning before we hear the sound of thunder.	2	2	2	2	2
Sound waves	2	2	2	2	2

Key

1 = What causes sound?; How is sound produced?; What are the characteristics of sound?

2 = How does sound travel?

3 = How is sound received?; How do we hear?

Appendix L

Grade Four Science Quiz - Sound

Circle the letter of the best answer.

1. Sound from a ringing fire alarm travels out:

    a. in one direction
    b. in two directions
    c. in all directions

2. An echo can be heard when sound waves:

    a. bounce back
    b. travel through water
    c. travel through air
    d. are very loud

3. In order to make a higher pitched sound, move a card over comb bristles:

    a. fast
    b. slowly

4. Fish can hear sound because they:

    a. have ears
    b. have ear drums
    c. feel vibration through their bodies
    d. jump out of the water to listen

5. Your partner is tapping a pencil at the end of a long wooden table. You listen to the sound through the air then put your ear to the table and listen. Which sounds louder?

    a. tapping sound heard through the air
    b. tapping sound heard through the table

6. If the ear drum can not vibrate because of injury or illness, a person may become ______________________________.

7. In science class you struck a tuning fork on a rubber puck.

    a. What did you hear? ______________________________

    b. What did you see? ______________________________

    c. What did you feel? ______________________________

d. What happened when you touched the ringing tuning fork to your desk top? ______________________________

8. How can you make a stretched elastic vibrate? __________

____

9. Two machines that make sound louder are:

a. ____________________

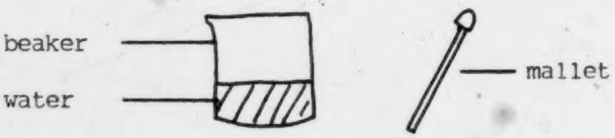
b. ____________________

10. Two things that could be put in a room to absorb or reduce sound are:

a. ____________________

b. ____________________

11. You are tapping a beaker of water to make sound. (see sketch)



What could you do to make the sound louder? ___________

____

What could you do to make the sound lower? ___________

____

12. A flying animal that uses echoes to navigate and to find its food is the ______________.

13. How does sound travel? __________________________

____

Appendix M

Children's Initial Interview Questions

1. How is Sound made?

   What things can make sound? How do these things make sound? What causes sound? How is sound made?
   If the child uses the word vibration, then: Can things make a sound if there is no movement or vibration?
   Can sounds be different from each other? What are some sounds that are different from each other?
   Can we make things sound louder or softer? How?
   Can we make things sound higher or lower? How?
   How do musical instruments make sound?

2. How does Sound travel?

   When the bell rings for recess, how can we hear the sound of the bell? How does that happen?
   If the child talks about sound being able to move or travel, then: How does sound travel? Can sound travel through things?
   Can sound travel through some things better than others?
   What can you tell me about echoes?

3. How is Sound received?

   How do we hear sound? Are some people unable to hear sound?
   What things or objects can help people to hear better?
   Do some animals hear better than other animals? Is there any way to tell if an animal can hear really well by just looking at the animal?

4. Do you know anything else about sound that we have not already talked about?

5. Sources of Ideas

   How did you get to know all these things about sound?

6. New Vocabulary

   What do you think the following words mean: vibration, energy, and matter?